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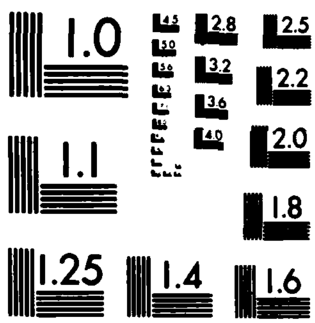
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DEVELOPMENT OF DESIGN AND ECONOMIC
PARAMETERS FOR PASSIVE SOLAR SYSTEMS

THESIS

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AFIT/GEM/LSM/84S-10

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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AFIT/GEM/LSM/84

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This thesis provides the Air Force design manager with a three phase method of determining the economic feasibility of passive solar heating for a given Military Construction Project. In the first phase, guidelines are presented for preliminary sizing insulation levels and solar collection (glazing) area based on the building location and size. Next, the second phase presented a quantitative energy analysis to achieve an accurate estimate of the energy savings of a passive solar building using the guidelines from the first phase. Finally, The third phase presented a method for economic analysis of passive solar systems using life-cycle costing. This method determines whether the energy savings justifies the incremental increase in construction cost based on a 25 year payback period.

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DEVELOPMENT OF DESIGN AND ECONOMIC PARAMETERS FOR PASSIVE SOLAR SYSTEMS

THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Masters of Science in Logistics Management

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Abstract

In order to reach the energy consumption goals established by Executive Order 12003 and Public Law 95-356, the Air Force must integrate conservation measures with present technology. This analysis generates target design and economic parameters for one such technology -- passive solar systems.

This thesis provides the Air Force design manager with a three phase method of determining the economic feasibility of passive solar heating for a given Military Construction Project. In the first phase, guidelines are presented for preliminary sizing insulation levels and solar collection (glazing) area based on the building location and size. Next, the second phase presented a quantitative energy analysis to achieve an accurate estimate of the energy savings of a passive solar building using the guidelines from the first phase. Finally, The third phase presented a method for economic analysis of passive solar systems using life-cycle costing. This method determines whether the energy savings justifies the incremental increase in construction cost based on a 25 year payback period.

METHOD FOR DETERMINING DESIGN AND ECONOMIC PARAMETERS OF PASSIVE SOLAR SYSTEMS

I. Introduction

Purpose

This report will introduce a step-by-step procedure for the base level program manager to ensure the inclusion of pertinent passive solar system data in the Military Construction Program (MCP) project booklet. Also, this report provides a complete and simplified method for determining economic feasibility of passive solar systems in new Air Force facility construction. The Air Force, along with the rest of the nation, recognizes the staggering energy cost and looks for a way to combat these costs in the future. Passive solar design is part of the answer; but, the Air Force needs a method to simplify the inclusion of the passive solar design in future construction. In order to maximize the use of passive solar systems where economically feasible, Air Force requirements must be clearly documented and communicated to the design Architectural Engineer (A-E). The vehicle of communication is the project booklet.

Justification

During the 1973 Arab oil embargo, energy surfaced as a national priority. The United States, along with many other nations, re-evaluated its energy policy. The United States realized that "our energy systems have been developed on the basis of large, inexpensive supplies of fossil fuel, and those traditional fuels exist in finite quanity [Stanley, 1981:22]."

Estimates of the recoverable crude oil in the world vary and are summarized in Table 1.1. The Global 2000 Report to the President points out that approximately 2000 billion barrels of oil were available to the world population at the start of oil exploration. Since then, 339 billion barrels have been consumed, thereby leaving 1661 billion barrels on total reserve of which only 646 billion barrels have been discovered. Therefore, over 1,000 billion barrels of oil need discovering in order to reach the 1661 billion mark (Global 2000, 1980). These figures are approximate; but they emphasize the reality of crude oil as a finite quanity. In that, if production remains constant, as research seems to suggest, discovered reserves will deplete in 30 years and total crude oil resources will deplete in 77 years (Global 2000, 1980). Oil supplies 47% of the world's energy, of which the United States consumes one-third; the impact of crude oil depletion is evident (Global 2000, 1980).

Table 1.1 (Global 2000, 1980:189)

Estimates of World Ultimate Production of
Crude Oil Made Since 1977
(Billions of barrels)

J.D. Moody &	Mobil Oil Corp.	1,800-1,900
	H.H. Emenik	
Richard L. Jody	Sun Oil Co.	1,952
H.R. Warman	BP, Ltd	1,800
William Verneer	Shell	1,930
H.R. Warman	BP Ltd	1,915
J.D. Moody &	Mobil Oil Corp.	2,000
	R.W. Esser	
M. King Hubbert	U.S. Geological Survey	2,000

Along with the fear of complete depletion of crude oil, the United States must evaluate its dependence on imported oil. The United States imports over 50% of its oil and will be adversely affected by any change in availability. Global 2000 states:

> there is a very real possibility that the surplus production capacity in OPEC will disappear as early as 1985 and as late as 1990 (Global 2000, 1980:170).

This statement alludes to the fact that OPEC nations may practice self-constraint in production in order to control the depletion of their main resource. The energy situation strongly encourages the United States to search for ways to reduce energy consumption.

Since depletion of oil resources is a real possibility, the United States must turn to other energy sources, and in all likelihood, coal will fill the gap between energy demand and supply (Global 2000, 1980). Coal use creates problems of its own -- such as, adverse environment impacts. In that, increased coal use will increase emissions of carbon dioxide and sulfer dioxide.

Scientists attribute carbon dioxide to causing a greenhouse effect within the atmosphere. The effect causes a gradual heating of the earth's surface, and if carried to extremes, will alter the earth's climate significantly. For example, due to the melting of ice in polar regions, the sea level has risen more than four inches since 1940, and this rate triples that of the previous 50 years. If the entire ice sheet of the Antartic melted, then the sea level would rise 250 feet, enough to flood most of the world's coastal cities (Recer, 1982).

Sulfer dioxide is connected with the problem of acid rain. That is, sulfer dioxide is carried out of the air by water modecules to the soil or water. Once in the environment, sulfer dioxide lowers the PH level, thereby causing a slow killing of all living organisms (Hodges, 1977).

The other energy option is not without its hazards. Nuclear power will always have it opponents who point to the Three Mile Island accident. An accident or radioactive meltdown will severely effect the environment. Besides the nuclear safety question, the other unanswered question is "where do we put the radioactive waste [Global 2000, 1980:37]."

Discussion to this point has focused on the issues of oil as a depleting resource and the viable options having consequential effects on the environment. The need for a clean and renewable energy source is clear. By the year 2000, the United States' energy demand will grow from the present 80 quads per year to approximately 143 quads per year (Global 2000, 1980). A quad is defined as a million billion

BTU´s; 1 BTU is the amount of energy needed to raised one pound of 40 °F water 1 °F. Once filtered by the atmosphere, the sun´s rays input 90 quads per day to the 48 contiquous states (Evans & Suptic, 1981). The figures, comparing the 80 to 143 quads per year needed to fulfill the United States´ energy demand and the 90 quads per day received from the sun, emphasize the importance for the United States to pursue solar energy as a viable substitute for fossil fuels -- the finite quanity. With this in mind, passive solar design can help harness this free, clean, and renewable energy source; and therefore, enter as part of the energy solution. The Air Force is in the process of searching for ways to standardize the inclusion of passive solar systems into new facility design.

Without proper guidance, the approach is haphazard as to where passive solar systems should be addressed. Emphasis must be on an energy conscious design from the very beginning of the conceptualization phase of programming (Fig. 1.1). Sources estimate that 10 to 20 percent of the potential energy savings can be recognized in the development of the design program (AIA, 1983). The design program, refered to as the project booklet by the Air Force, is the document that describes the design problem by including the client´s needs, climatic conditions, site information, codes and regulations, and budget figures (AIA, 1983). This phase leads directly into what is often referred to as the schematic design phase where words are converted into archetictual concepts. The project booklet is what conveys the Air Forces´ desires to the design A-E. Therefore, in order for the Air Force to be able to recognize the full benefit of

an energy conscious design, the desires of the Air Force must be explicitly communicated in the project booklet.

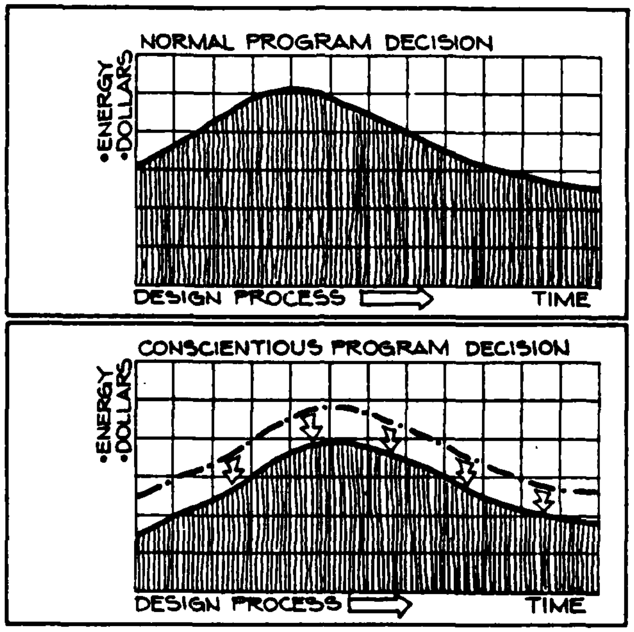


Figure 1.1 Program Decisions (AIA, 1983:3.1)

Defining Passive Solar Energy

The National Bureau of Standards defines a passive solar system as

> An assemble of collectors, thermal storage device(s) and transfer media which converts solar energy into thermal energy and in which no energy in addition to solar is used to accomplish the transfer of thermal energy (Allen & Transmeier, 1980:4).

A more simplified definition is presented by J. Douglas Balcomb:

> Passive systems are defined, quite generally, as systems in which the thermal energy flow is by natural means, that is, by conduction radiation, and natural convection (Paul, 1979:1).

Both of the definitions emphasize energy transfer by natural means, and in this light, the design of a structure must facilitate the natural transfer. Passive solar systems provide heating, cooling, and natural lighting (SERI, 1980).

Problem Statement

Through the issuance of policy letters, the Air Force provided the vehicle to encourage the use of passive solar design in future construction; however, no systematic method exists for ensuring it is used where determined economically feasible. Also, research into expanding the economic criteria involved in evaluating feasibility of passive solar systems is needed.

Research Question

This project is a follow-on to previously completed work by Captains Baldetti and Lockard; therefore, the research question remains basically the same. How can designers of the Air Force structures quickly and reliably determine whether a passive solar system is cost justified given the designer's local conditions and then ensure their recommendation is given proper consideration by the A-E?

Procedure

First, passive solar heating techniques will be examined followed by a review of geographical climatic conditions, building orientation, and conservation factors effecting passive solar system performance.

Second, current design and sizing procedures will be identified, high-lighting those particularly beneficial during the preliminary design stage of new facility construction. Third, a review of applicable Air Force policy and guidance will be conducted. Fourth, the Baldetti and Lockard thesis effort will be summarized. Fifth, a telephone interview will be adminstered to determine the design manager's involvement with passive solar systems. Sixth, a step-by-step procedure will be formulated to assist the base level engineer in systematically approaching the problem of justifying the use of passive solar systems and ensuring consideration is given to passive solar systems in the development of design concepts by the A-E. Finally, worksheets will be laid out with sufficient documentation so as to facilitate incorporation as a computer program at a later date.

Scope and Limitations

This research report is focused on evaluating passive solar heating applications in the preliminary design stage of single and multi-story structures. New construction will be mainly addressed. No discussion of active solar systems or passive solar cooling systems will be presented. Analysis will be limited to military installations in the continental United States, and will assume that normal passive solar techniques (i.e. insulation and building oriented for maximum southern exposure) will be incorporated into the building design.

Economic evaluation will use life-cycle costing and concentrate on incorporating passive solar heating into the solar savings factor.

The analysis will generate a series of worksheets, complete with documentation, that can be used at base level for determining the economic feasibility of passive solar systems. The structure of the worksheets will facilitate adaptation to a computer program. Also, the analysis will provide the foundation for a systematic procedure for ensuring pertinent passive solar data is included in the project booklet. This procedure could be incorporated Air Force wide as a policy letter or some other media.

To this point the discussion has concentrated on making the reader aware of the energy problem and of a possible solution to the problem — institutionalizing the use of passive solar systems. In the next chapter, attention switches to familiarizing the reader with the various passive solar systems and the considerations and techniques involved in designing a passive solar system. Also, the current Air Force guidance is introduced in order to have the proper prospective for further discussions and generate a feel for where the pressure originates to reduce Air Force energy consumption. Finally, Captains Baldetti and Lockard thesis effort is summarized.

II. Literature Review

A review of literature in the arena of passive solar design focuses on comfort, passive solar techniques, employment of passive solar concepts, Air Force guidance in passive solar design including the original stimulus for the attention given to reducing energy consumption, and a summarization of Baldetti's and Lockard's thesis.

Human Comfort

The human body maintains comfort by applying the natural processes of convection, evaporation/respiration, and radiation (Jonovich, 1982). These processes are regulated by environmental factors -- such as, ambient temperature, mean radiant temperature, air speed and humidity (Jonovich, 1982; Kreith & West, 1980). In that, using the nature processes, the environmental factors determine to what extent the body regulates body temperature (Fig. 2.1). In the following discussion, the natural processes and environmental factors determine a cause and effect relationship.

Ambient Temperature. Air and body temperature differences determine the rate of heat loss or gain through convection (Jonovich, 1982). Obviously, the greater the difference, the greater the force to move from the higher energy state to the lower one.

Mean Radiant Temperature (MRT). This is the measure of average surface temperature of all the surroundings. The body can

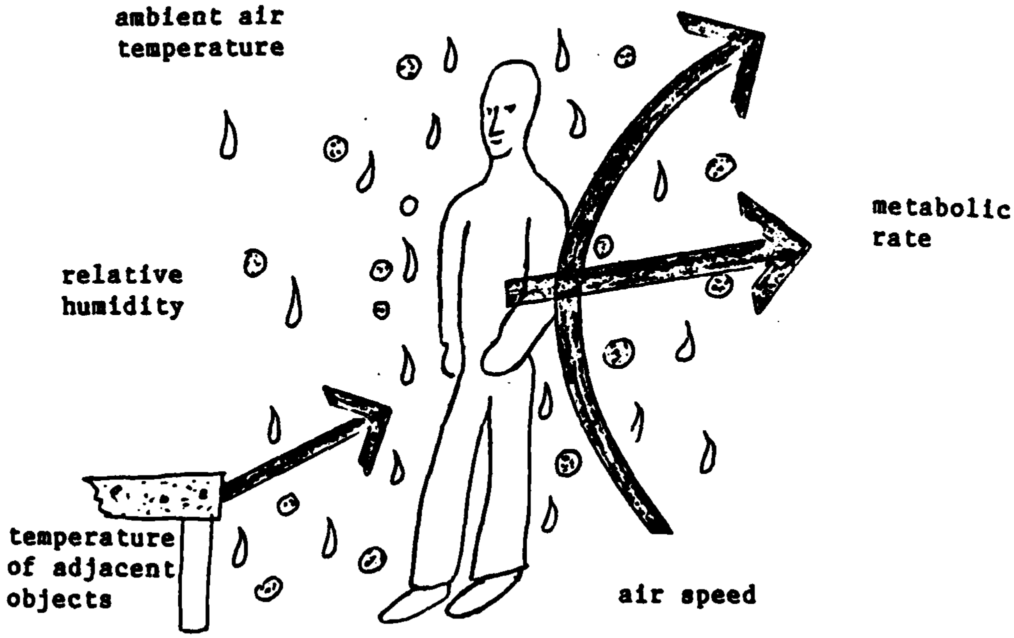


Figure 2.1 Body Heat and Environmental Conditions

exchange heat through radiant transfer with its surrounding surfaces (Jonvich 1982; Krieth & West, 1980). According to a report referenced by Baldetti and Lockard, " a 1°F change in MRT has a 40% greater effect of body heat loss than 1 °F change in air temperature [Baldetti & Lockard,1983:9]."

Air Speed. Movement of air induces heat gain or loss due to convection (Kreith & West, 1980). For example, the wind chill tables, published in many journals, show that at a given ambient temperature, increasing wind velocity accelerates heat loss.

Humidity. The moisture content of the air affects the rate at which the body loses heat by evaporation. If the body is unable to dissipate energy to its surroundings due to high humidity, the body will experience discomfort (Jonovich, 1982).

Human Comfort and Passive Solar Design. In order to actively pursue the idea of comfort within buildings, energy conservation must be considered first -- in particular, reducing energy losses through conduction and infiltration (Jonovich, 1982). In this manner, passive solar design attempts to make structures air tight by using insulation, weatherstripping, windbreak, protected entryways, etc. (Jonovich, 1982). For example, a passive solar design structure can have as little as 0.3 to 0.6 air changes per hour (ACH), while a conventional structure usually has 1.0 to 1.5 ACH (Baldetti & Lockard, 1983). With is in mind, passive solar building projects a comfortable environment at a temperature of 65 ^{o}F (Baldetti & Lockard, 1983).

Also, passive design approaches comfort on another level. Mean radiant temperatures increase with the use of walls, floors, and windows as storage and transfer media for solar energy. This allows for lower room temperatures to seem comfortable (Baldetti & Lockard, 1983).

Passive Solar Techniques

In the following section, various passive solar designs will be discussed. The review is not exhaustive and only covers some of the more common uses of passive solar systems. These systems can be

divided into three general categories -- direct, indirect, and isolated gain -- and have some overlap (Kreith & West, 1980).

Direct Gain. Direct gain is the oldest and most common concept used in passive solar design. This application uses direct sun rays to warm the living area of a structure. The sun's rays enter through a glazing (window or transparent material) surface, usually from a large south facing wall, and exposes the conditioned area (Paul, 1979). For the conditioned area to more efficiently absorb the solar gain, the floor and/or wall must be of substantial dimension to store and release the solar gain when room temperature lowers (Kreider & Kreith, 1981). Along with floor and wall materials that will readily absorb and later distribute solar gain, double glazing material is used to minimize heat loss (Paul, 1979). Figure 2.2 exemplifies direct gain.

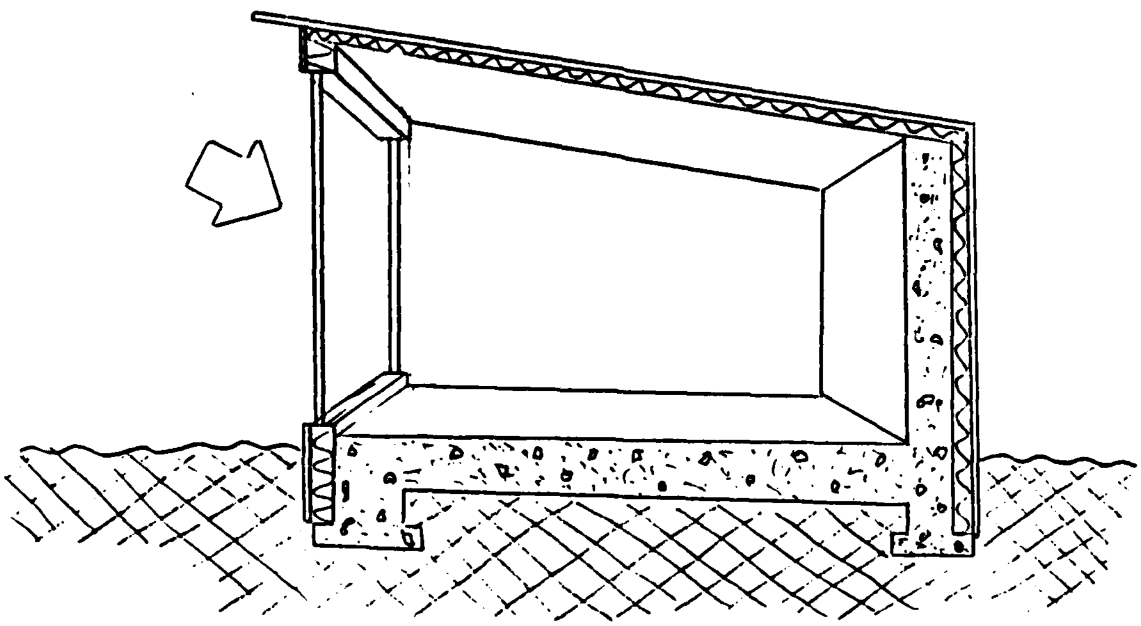


Figure 2.2. Direct Gain

Some of the advantages of this design are simplicity, ease of construction, and use of glass on the southern face of the facility to admit heat and light. Disadvantages include interior temperature swings, glare and ultraviolet degragation of interior surfaces, and loss of privacy due to large glass areas (Jonvich, 1982).

Indirect Gain. Indirect gain design constructs a mass between the glazing area and the conditioned space (Kreith & West, 1980). The sun's rays absorb into the mass which in turn releases the solar gain to the adjoining space and a strong natural thermal bound is achieved. Some examples of how to employ indirect gain follow.

Mass Trombe Wall. The trombe wall is similar to direct gain, in that, a large glazing area of southern orientation is exposed to the sun. The differnece is that directly behind the glazing is a wall consisting of concrete, adobe, stone, and composites of brick, block and sand (Paul, 1979). The wall, a storage mass, absorbs solar gain through the glazing and distributes the gain to the adjoining space by natural convection (Jonovich, 1982). Different variations of this concept exist. Figure 2.3 gives a basic pictorial of a trombe wall.

Some of the advantages of this design are reduced temperature swing, elimination of glare and ultraviolet problem, well advanced state-of-the-art, and time delay in release of solar gain. The latter advantage provides warmth in nonsunshine hours (Jonovich, 1982).

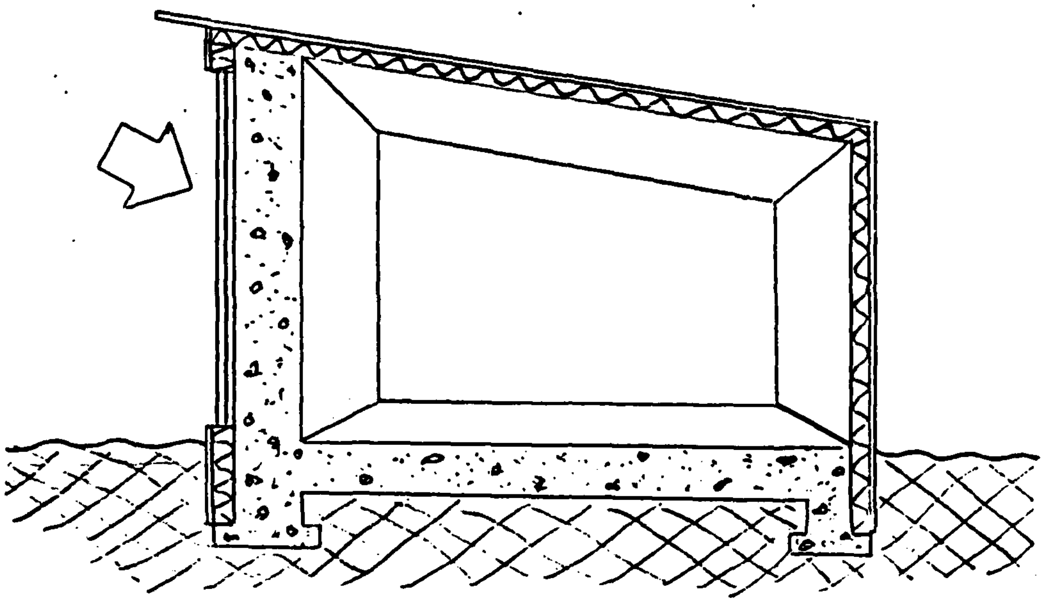


Figure 2.3. Trombe Wall

Some disadvantages are the need for two walls, cost of massive walls, heat loss through the glazing in severely cold climates, and the giving up of valuable space (Vol I, 1980).

Water Trombe Walls. The water wall employs the same principals as the mass trombe wall. However, with water as the storage media, greater attention is given to volume of the wall and movable insulation. Water dissipates and collects solar gain more rapidly than solid mass (Paul, 1979). Figure 2.4 depicts a water trombe wall.

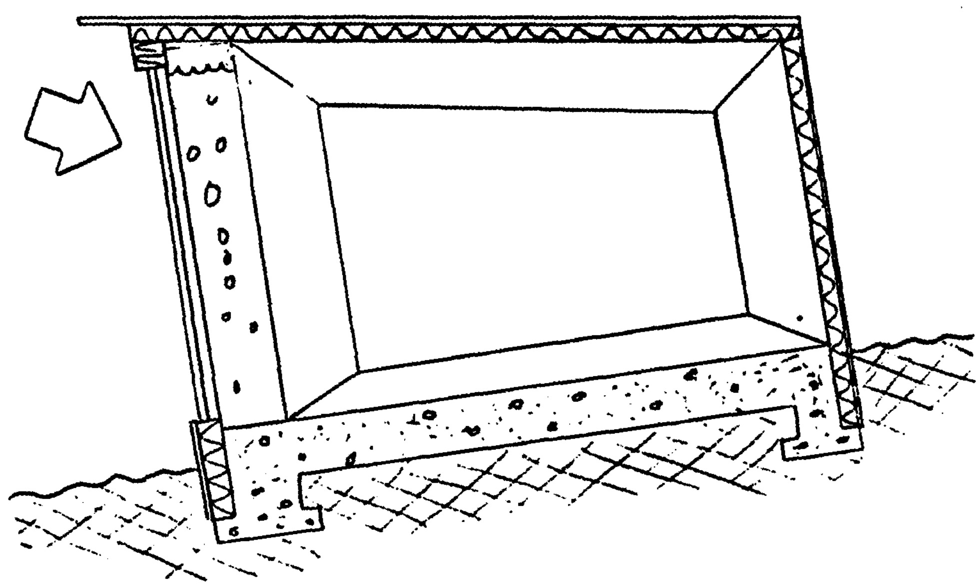


Figure 2.4. Water Trombe Wall

The rapid dissipation and collection of solar gain by the water wall can be an advantage or disadvantage and requires careful design consideration, in that greater mass and movable insulation must be considered in order to moderate the swings in temperature (Kreider & Kreith, 1981). Water walls are at times more convenient than mass walls since the water maintains a more uniform temperature thoughout its thickness, thereby lowering the absorption surface temperature (Vol I, 1980).

<u>Roof Pond.</u> The roof pond technique employs water evenly distributed on the roof over all living areas, and direct exposure to

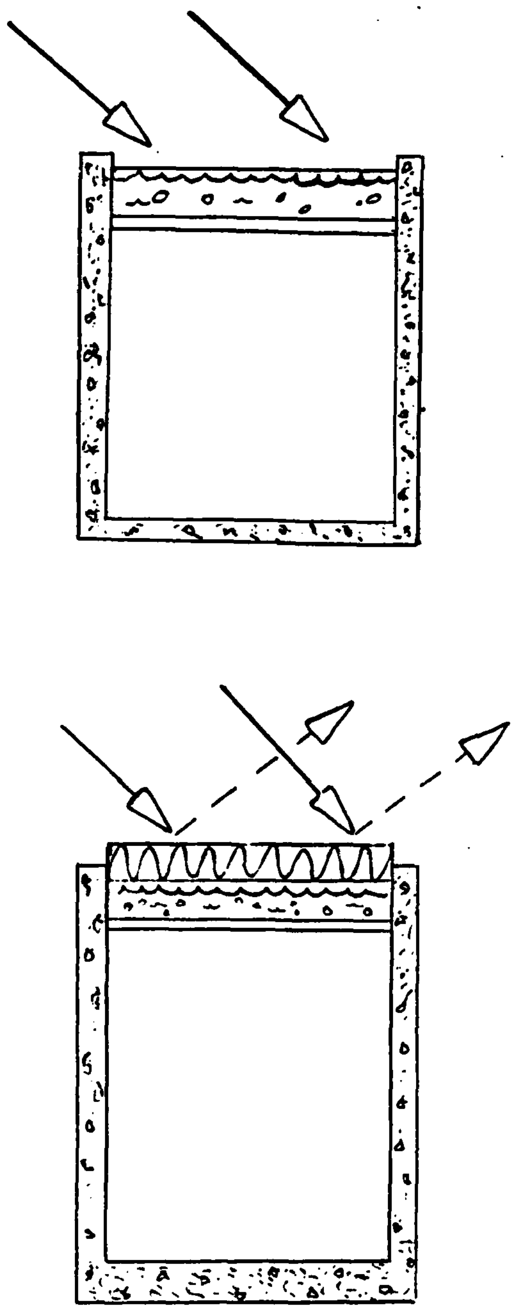


Figure 2.5. Roof Pond

the sun achieves solar gain (Fig. 2.5). Because the solar gain radiates to the living space, it is imperative the pond and conditioned space be in close proximity to facilitate solar gain exchange (Paul, 1982). Again, and more importantly, moveable insulation must be considered to reduce heat and evaporation losses (Kreider & Kreith, 1981).

Some of the advantages of roof ponds are uniformity of distributing the heating and cooling effects, reduction in temperature swings, and elimination of glare and ultraviolet problems (Vol I, 1980). Some disadvantages are the heavy weight on the ceiling structure and lack of refinement in the state-of-the-art which is needed before generic application (Vol I, 1980).

Isolated Gain. In an isolated gain system, there is a definite separation between thermal storage and the conditioned space (Krieder & Kreith, 1981). Common examples of isolated gain are sunspace and thermosiphon.

Sunspace. Sunspace collects solar gain in a secondary area, such as a greenhouse, through a glazing surface for later distribution to the conditiond space (Fig. 2.6). Again, southern exposure is important and some type of storage media is necessary in the floors or walls to retain solar gain during nonsunshine hours (Paul, 1979).

Some of the advantages of this design are adaptability to existing structures, offering of additional living space, providing solar gain, and acting as a buffer zone for the conditioned space to

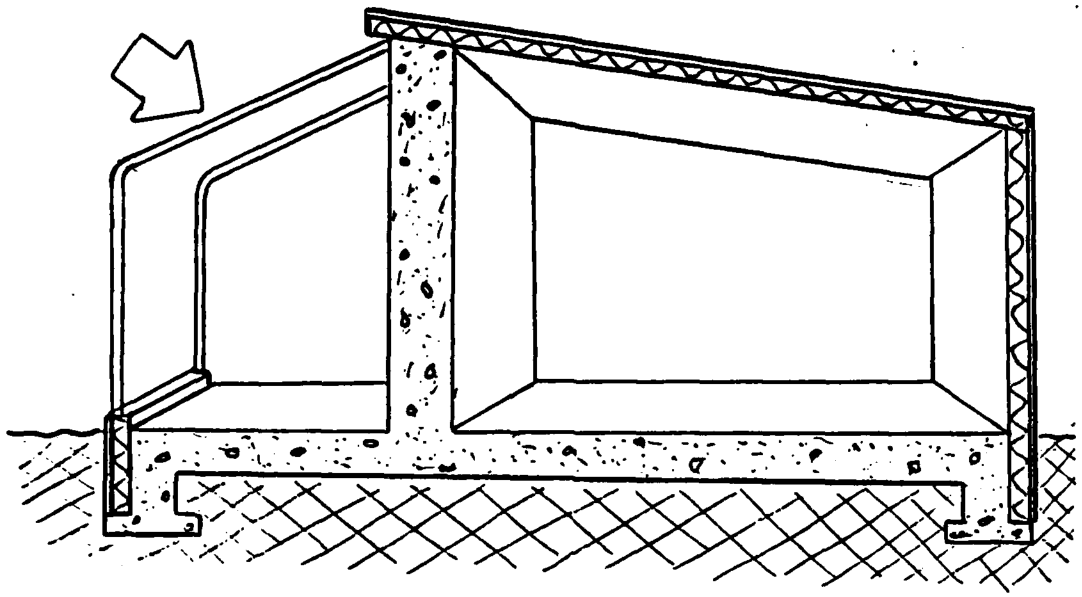


Figure 2.6. Sunspace

reduce heat loss and temperature swings (Jonovich, 1982). Disadvantages include cost and difficulty in estimating the solar gain to the conditioned space.

Thermosiphon. The final passive solar design technique discussed is the thermosiphon. It uses the principal that hot air rises and cold air falls, in that, an enclosed glazed surface is exposed to the sun's rays and passes solar gain to the entrapped air media (Fig. 2.7). The warmer air then rises to a storage mass and cooler air falls causing a continuous cycle (Kreider & Kreith, 1981).

An advantage to the system is the low cost in incorporating it into the facility design. A disadvantage is the careful engineering and construction considerations needed to ensure proper airflows (Vol I, 1980).

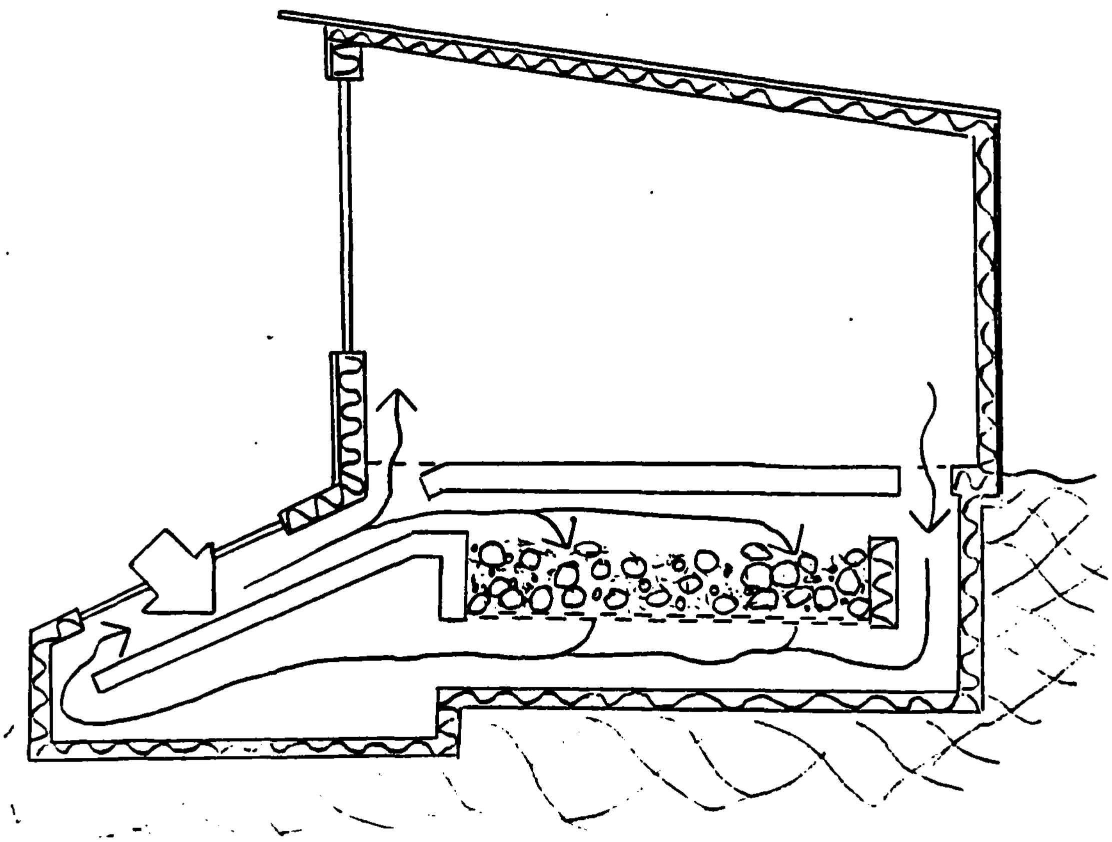


Figure 2.7. Thermosiphon

Considerations for Passive Solar Applications

This section identifies the many factors involved in the consideration of passive solar energy applications. Of major importance is climate, building orientation, and conservation levels (eg. insulation values).

Climate Conditions. Climatic conditions that apply to broad regions constitute major climate conditions. Generalized regions are classified by several different means.

Traditional Climatic Regions. These regions are presented by the Department of Energy (Fig. 2.8). The four major subdivisions -- cool, temperate, hot-humid, and hot-arid -- are based on humidity, average temperature, and solar radiation.

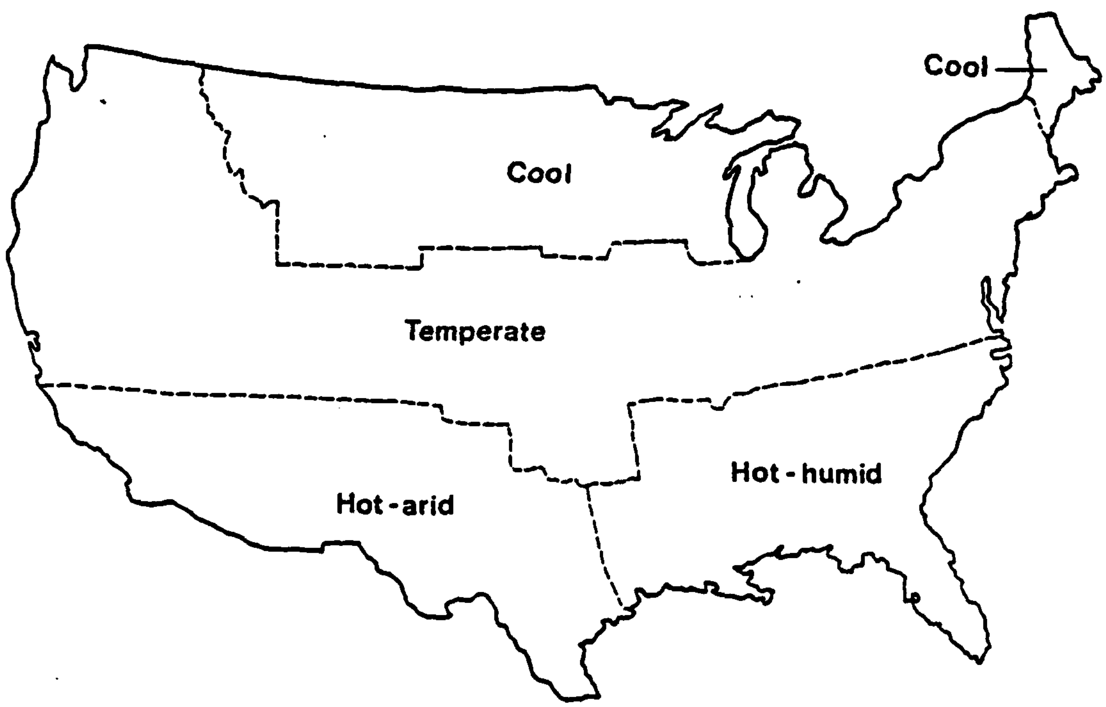
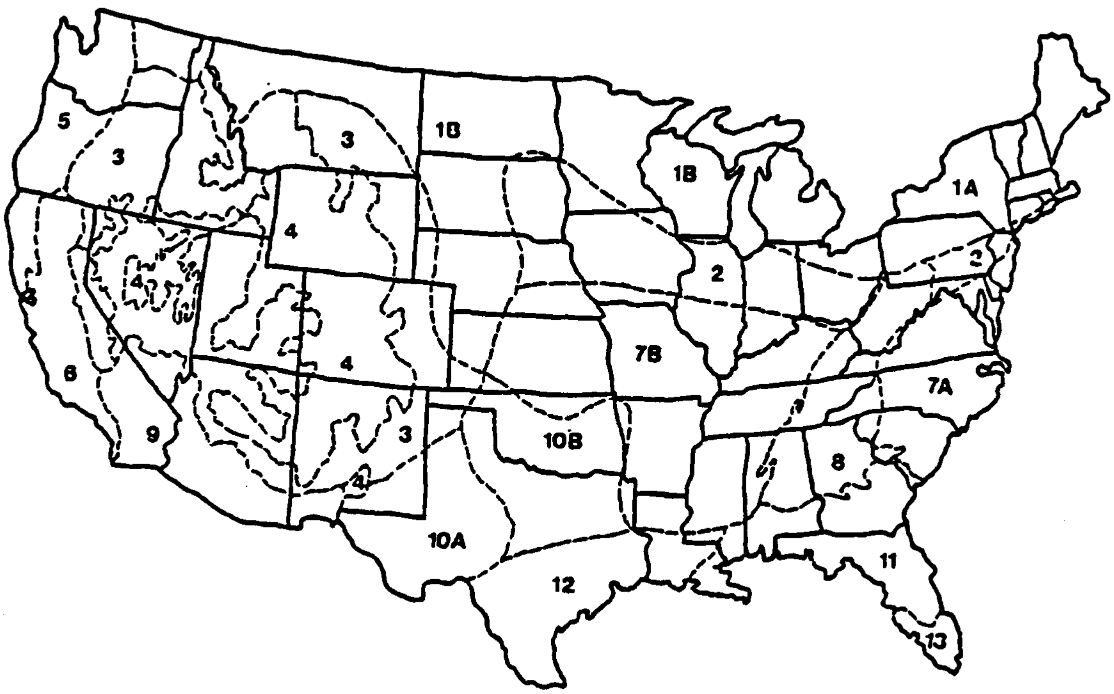


Figure 2.8 Traditional Climate Regions
(Baldetti & Lockard, 1983:24)

<u>AIA Regional Guidelines for Building Passive Energy Homes.</u> The AIA divided the United States into 13 climatic regions (Fig. 2.9). These regions seemed to have been determined "on a somewhat of a subjective basis [Baldetti & Lockard,1983:22]." However, the regions are named according to the architectural concept most appropiate for that area. This feature makes the identifying of potentially feasible passive solar systems an easy task.



Reference cities:

1A Hartford, Conn.
1B Madison, Wis.
2 Indianapolis, Ind.
3 Salt Lake City, Utah
4 Ely, Nev.
5 Medford, Ore.
6 Fresno, Calif.
7A Charleston, S.C.
7B Little Rock, Ark.
8 Knoxville, Tenn.
9 Phoenix, Ariz.
10 Midland, Tex.
10 Fort Worth, Tex.
11 New Orleans, La.
12 Houston, Tex.
13 Miami, Fla.

Figure 2.9 AIA Climatic Regions
(Baldetti & Lockard, 1983:23)

Degree-Day Climatic Regions. Different regions are based upon the average number of heating degree days per month (DD) and are presented in Figure 2.10 on the next page. DD is

> the summed difference between a fixed base temperature and the daily mean outdoor temperature. Only positive differences are accounted, that is outdoor mean is less than the base temperature (Vol I, 1980:73).

A base temperature of 65° F is used in the DD computation.

Conservation Climatic Region. These regions are based on the importance of conservation measures (Fig. 2.11, also on the next page). The amount of conservation needed is link directly to the region based on the ratio of solar radiation available to the heating degree days (VT/DD). This method of categorizing climatic regions gives a rough idea of a passive solar system's potential in a given region (Wray, 1983).

Building Orientation. The orientation of the building effects the potential energy savings in several ways. First, building orientation determines the amount of natural lighting available to meet the building's lighting requirement (SERI,1981). Second, orientation, with respect to the prevailing direction of severe winds, influences the rate of infiltration in the structure (SERI,1981). Finally, in order to facilitate heat gain, the building orientation should allow maximum exposure of the southern surface. However, local shading situations and weather condition may necessitate departures from true south. Variations from true south effect solar system performance, and general rules of thumb for degradation of performance are as follows (Vol II, 1982):

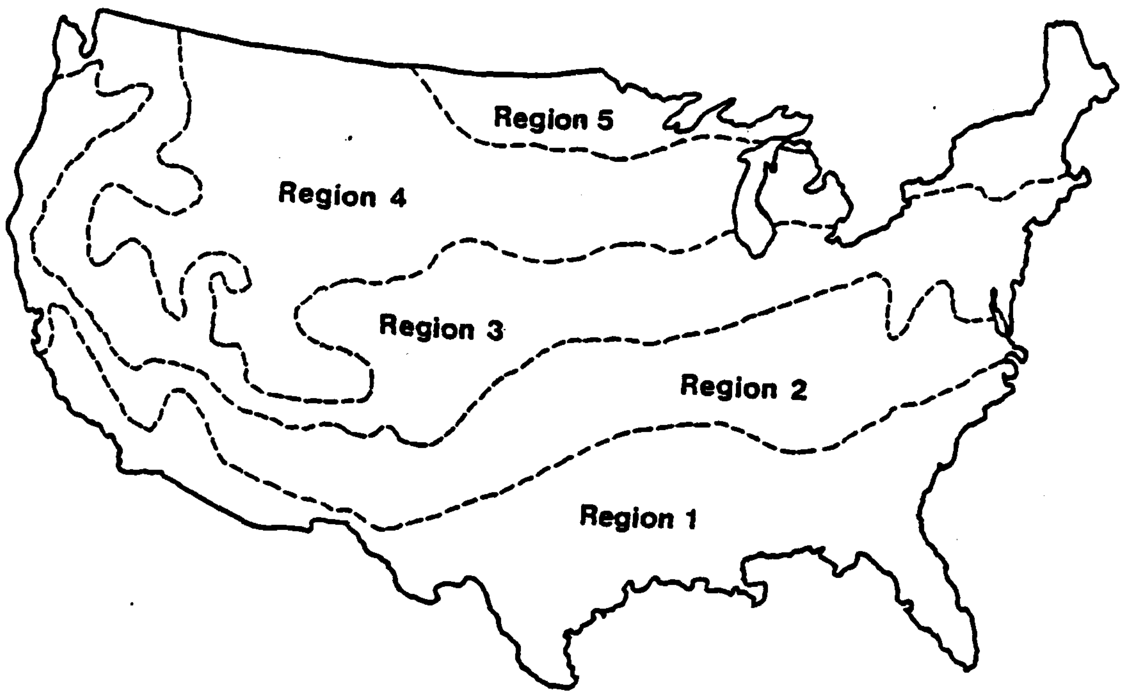


Figure 2.10 DD Climate Region
(Baldetti & Lockard, 1983:25)

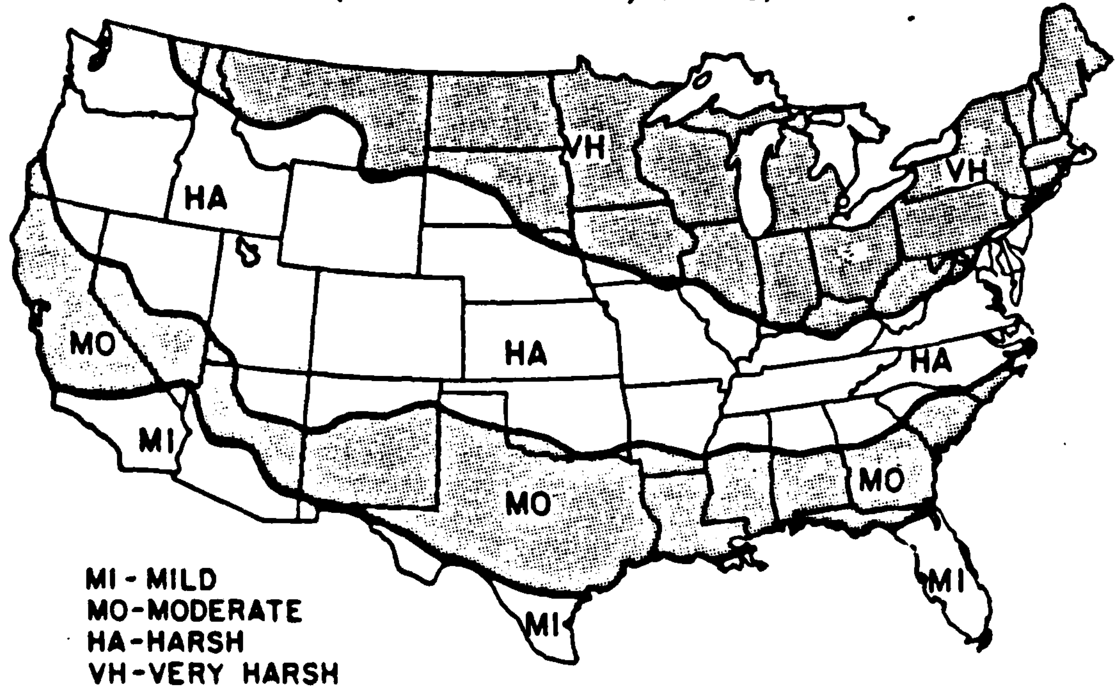


Figure 2.11 Conservation Climate Regions
(Wray, 1983:15)

5% decrease at 18 degrees east or 30 degrees west
10% decrease at 28 degrees east or 40 degrees west
20% decrease at 42 degrees east or 54 degrees west

A method to quantify reduction in system performance by altering glazing area is presented below (Wray, 1983):

$$Ac = (Ac)south * [\cos(4/5)\theta] \qquad (1)$$

where

θ = degrees off of true south with positive values for east orientation and negative values for west orientation

(Ac)south = collector area for true south orientation

<u>Conservation.</u>

> Conservation makes the passive solar system's job easier; likewise, passive solar reduces the need for auxiliary heat well below levels attainable by conservation alone. Good thermal design consist of achieving a proper balance of these two strategies' (Balcomb, 1983:2).

In this light, solar designers approach the designing of a facility with the thought "first insulate, then use solar [Vol III, 1982:14]." But, problems arise when the designer attempts to find an optimum mix between conservation levels and solar system size. For example, in the case of wall insulation, a designer may decide on R10 instead of R5 at an additional cost of 100 dollars. The energy saved is quantified at 100 dollars per year for this improvement. After seeing the results, the designer decides on increasing the R-value to 20. The cost is an additional 200 dollars but the annual energy saved is only $50 dollars (Vol III, 1982). In the first improvement, the payback period of the investment was one year while in the second case

the payback period was four years. This discussion represents the law of diminishing returns, in that as investment dollars increase to achieve a higher R value the corresponding energy savings decrease. The same presentation could be used for solar system sizing. That is, initially the passive solar system handles a large portion of the heating load; but, as the size of the system is enlarged, the incremental energy savings decrease. With respect to conservation levels,

> an optimum mix is achieved when the incremental cost/benefit of each conservation option is just equal to the incremental cost/benefit of the passive solar strategy being used (Vol III, 1982:16).

Therefore, in order to maximize energy saving for an investment, a mix of conservation and passive solar systems must be employed. This statement is quantified in a series of formulas for insulation in Passive Solar Handbook Vol III which are presented below.

1. $$R_{wall,\ ceilings,\ floors,\ E,W,N\ windows} = CF * (Cs / Cii)^{1/2} \qquad (2)$$

   Rwall
   ceilings
   floors
   E,W,N windows

where

Cs = passive system cost, \$/ft sq
Cii = insulation cost, \$/R sq ft

2. $$Rperimeter = 2.04 * CF * (Cs / Ci)^{1/2} - 5 \qquad (3)$$

where

Ci = insulation cost, \$/R lineal ft

3. $$Rbasement = 3.26 * CF * (Cs / Ci)^{1/2} - 8 \qquad (4)$$

4. $$ACH = 7.5 * (Cach / Cs)^{1/2} / CF \qquad (5)$$

where

Cach = cost to increase 1/ACH by 1, $/ft sq
CF = conservation factor based on location, solar system type and incremental cost with respect to fuel cost
ACH = air changes per hour

If the conservation levels are within 20% of this guidance, then the cost effectiveness of the design is not signficantly affected (Vol III, 1982). A simplification of these formulas is presented in Chapter III.

Current Design, Sizing, and Analysis Methods

The section contains an analysis of existing methods for designing, sizing, and analyzing passive solar systems. Design and analysis methods are categorized into four levels based on complexity of the method.

Level 1: Detailed Hourly Simulations.
Level 2: Simplified Simulations and Corrections.
Level 3: Automated Hand Methods (Programmable Calculators).
Level 4: Manual Methods

Manual methods are most useful for rules of thumb, design indicators, and guidelines which can be summarized in a few pages of graphs, charts, or nomograms (SERI, 1981). Since this report is aimed at providing general design parameters and guidelines to the base-level design manager, only the manual methods are discussed in this section. These methods are the Load Collector Ratio method, the Solar Load Ratio method, the Fast Solar Load Ratio method, and the Air Force Evaluation method.

Load Collector Ratio Method (LCR). The Load Collector Ratio method calculates the auxiliary heat requirement using a three-step process listed in the Passive Solar Design Handbook Vol III.

1. Obtain building information
   a. Building Load Coefficient (BLC)
   b. Projected area of solar glazing (Ac)
   c. Load Collector Ratio (LCR = BLC/Ac)

2. Use tables from Passive Solar Handbook
   a. Refer to desired city
   b. Refer to desired reference design
   c. Determine the annual SSF by interpolation
   d. Note the annual heating degree days (DD)y

3. Calculate the annual auxiliary heat
   Qaux = (1 - SSF) * BLC * HDDy

   where
   SSF = Solar Savings Faction

Advantages of the LCR are the ease and straightforwardness of the calculation. The main disadvantage is the assumption by the LCR method of 65^{o} F as the base temperature for the DD determination (SERI, 1980). The base temperature is a function of internal heat gain and thermostat set point as related by the following formula (Wray, 1983):

$$Tb = Tset - (Qint/BLC + 24Uc * Ac) \qquad (6)$$

where

Qint	=	internal heat gain
BLC	=	building load coeffient
Uc	=	steady state conductance of the glazing area (Appendix F)

A 65^{o} F base temperature allows a 5^{o} to 7^{o} F internal heat contribution which is representative of residential and small commercial buildings (Vol II, 1980). But, larger, people, and

equipment intensive buildings have internal heat gains greater than the 5^o to 7^o F range, thereby decreasing the DD figure used in the calculation of Qaux.

Also, the Solar Savings Faction (SSF) is not representative of the facility. The SSF quantifies the ratio of the amount of solar savings (energy savings) to the facility's net thermal load without the solar system (SERI, 1980). The SSF is related to the base temperature, in that it gives an indication as to what fraction of Qaux that can be supplied by solar. For example, if the base temperature is thought to be 65^o F, when in fact it is lowered by internal heat gains, the SSF will call for a larger glazing area based on the inflated DD figure in order to handle the preceived heating load. This larger glazing is not a design c. conomic optimal and may result in overheating of the facility.

Solar Load Ratio Method (SLR). The Solar Load Ratio method computes the auxiliary heat requirement in a complex manner. SLR is represented by the following formula extracted from Chapter F of the Passive Solar Design Handbook, Vol II:

$$SLR = (VT/DD) * \alpha / (LCR + G) \qquad (7)$$

where
- VT = amount of solar radiation transmitted through one square foot of solar glazing
- α = solar glazing absorptance fraction
- G = effective load coefficient of the solar glazing per square foot

This method provides a means for accounting for variables not considered in the LCR method -- such as, effects that modify the solar input, effects of the thermostat setting, and the effects of internal

heat generation (Baldetti & Lockard, 1983).

Fast Solar Load Ratio Method (FSLR). This method, presented in the Passive Solar Design Manual for Naval Installations, is similiar to the SLR method discussed previously. The FSLR method differs, in that it is based upon the nomogram in Figure 2.12. In the nomogram the scalar solar load ratio (SLR*) for specified value of the "a" parameter is plotted against the yearly heat-to-load ratio (Qaux/Qload)y (Wray, 1983). The "a" parameter is tabulated in the weather data tables presented Appendix G. In the table, the "a" parameter varies with the calculated base temperature at the facility location. The relationship between the scalar solar load ratio (SLR*) and the solar load ratio (SLR) is presented in the following equation (Wray, 1983):

$$SLR^* = F * SLR \qquad (8)$$

The F, G, and α values are tabulated as system-dependent parameters in Appendix F. Also, the weather parameter (VT/DD) is tabulated with weather data in Appendix G. Therefore, the only term that needs calculating is the LCR. As presented earlier, the LCR is simply the BLC divided by the solar glazing area (Ac).

Once the LCR is calculated and all other variables are obtained from the tables, the SLR* can be determined. Now knowing the SLR* and the appropriate "a" parameter, the yearly heat-to-load ratio is read from the nomogram. This ratio is instrumental in calculating the yearly auxiliary heat (Qaux) requirement of the facility that is determined by the formula (Wray,1983):

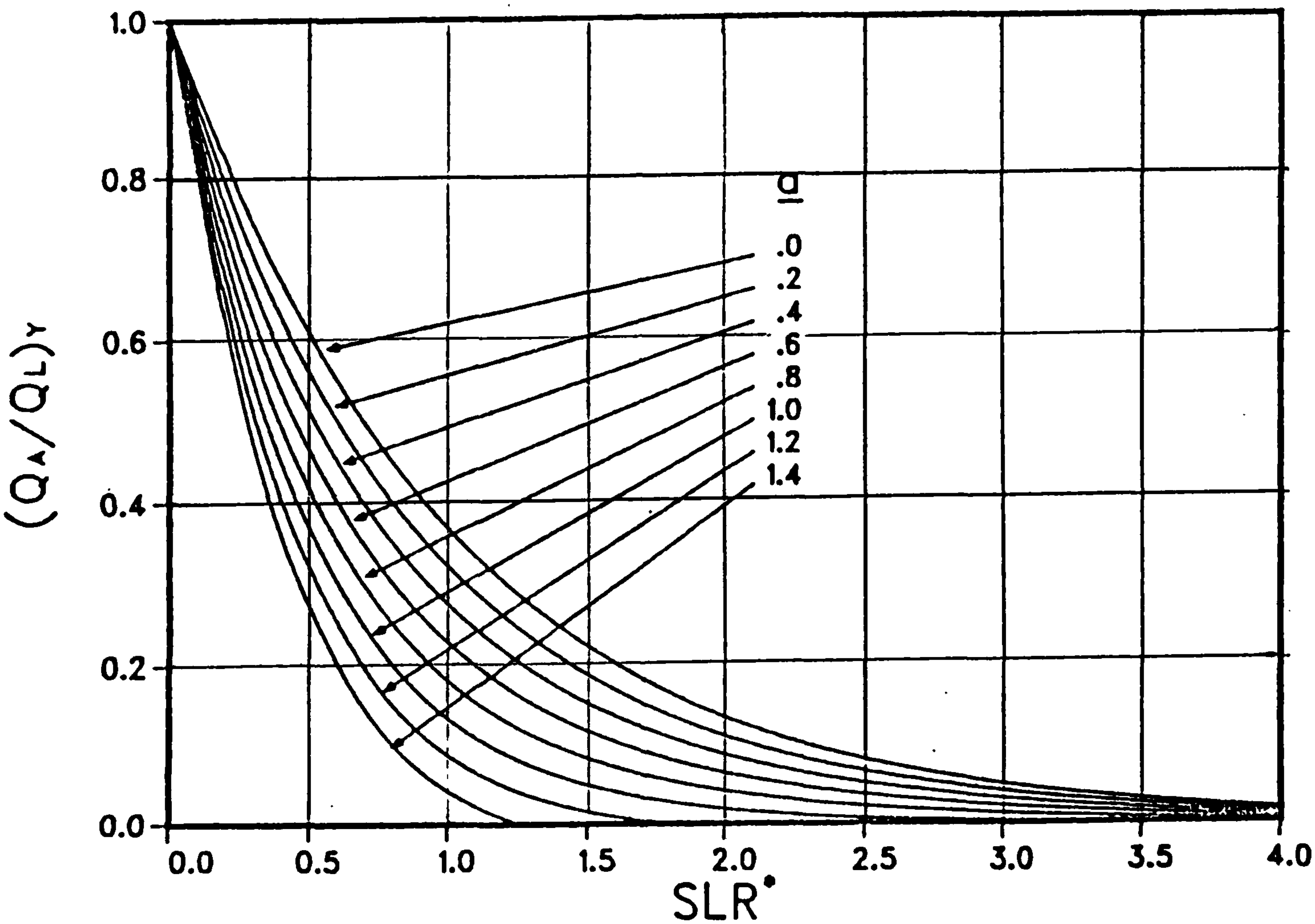


Figure 2.12. Yearly Heat-to-Load Ratio Nomogram
(Wray, 1983:31)

$$Qaux = (Qaux/Qload)y * (BLC + G * Ac) * DDy \quad (9)$$

Air Force Evaluation Method. The Air Force Evaluation Method is discussed in ETL 84-1. This procedure is intended to give an indication as to where passive solar systems have potential of being economically feasible. The discussion in this section is limited to the Air Force's method for determining the auxiliary heat requirement based on the contribution by the solar system.

The Air Force determines annual heating consumption by first making a few assumptions: 1) the build loss coefficient per square foot is 10 BTU per degree day per square foot per year (BTU/DD sf yr); 2) a base temperature of 65° F is used to determine heat degree days; 3) the SSF is in accordance with assumptions made in generating the map on page 18 of the Passive Solar Handbook, Vol III. Therefore, the Qaux is then equal to:

$$Qaux = SF * (10) * (DD) * (1 - SSF) \qquad (10)$$

The advantage of the Air Force evaluation method is that it gives a quick and easy process by which an installation's potential for passive solar systems can be judged. Some disadvantages are the assumptions being made, in that the base-level designer needs information (eg. DD, SSF, and building load coefficient) that is site and facility specific in order to make educated recommendations of passive solar systems to the A-E in the project book.

Air Force Guidance on Solar Energy Applications

In 1979, the United States Congress passed the Military Construction Codification Act (Public Law 97-214, paragraph 2857) which requires solar energy systems be considered in the design of all new military facilities where the use of solar energy can save fossil fuel. Furthermore, contracts for construction resulting from such designs shall include a requirement that solar energy systems be installed when proven cost effective.

To be considered cost effective, the difference between the original investment cost of the energy system for the facility with a solar energy system and the facility without a solar system must be recovered over the expected life of the facility. The expected life is set at 25 years. The cost effectiveness will be determined using the economic analysis techniques contained in the National Bureau of Standards (NBS) Handbook 135 "Life-Cycle Cost Manual for Federal Energy Management Program."

Recent Headquarters Air Force guidance on solar application has been provided by engineering technical letters (ETLs). ETL 84-1 "Solar Applications", dated 18 Jan 1984 was distributed to Air Force Major Commands and outlines current Air Force policies toward implementing passive solar technology.

In the Passive Solar section, this ETL refers to ETL 82-5 that separated passive solar applications into two categories, "normal" and "unique". Normal passive solar applications are general energy efficiency considerations and are part of any good building design.

Normal applications of importance to this report include building location, orientation and shape, window location and treatment, shading devices, overhangs, and insulation including night insulation for all windows. These applications do not require a special economic analysis for justification.

In constrast, unique passive solar applications require special economic analysis and must be proven cost effective by achieving a savings-to-invesment ratio (SIR) that is greater than 1. According to ETL 84-1, any application designed to provide heating, cooling, or daylighting (glazing more than 15% of area served) through passive solar means is considered a unique solar application. Examples of these applications are the direct, indirect, and isolated gain heating techniques described earlier in the chapter.

ETL 82-6 "Normal Passive Solar Applications", dated 30 Dec 1982 provides detailed descriptions of normal passive solar application. ETL 82-7 "Unique Passive Solar Applications", dated 30 Nov 1982 provides the same information for unique passive solar applications.

An underlying motivation for generating the Air Force guidance in this subject area is provided in the goals set by Executive Order 12003 which is being followed up with NEPA in 1985. Essentially the goals require the Air Force to reduce its energy consumption 20% of the 1975 figures by 1985. NEPA will require reductions of 25% in 1990, 30% in 1995, and 35% in the year 2000. The Air Force has targeted the use of solar energy as a means to reduce energy consumption in facilities, thus increasing the likehood of achieving the energy reduction goals set by the president and congress.

Baldetti and Lockard Thesis

The review of the thesis is divided into two areas. The first area is the telephone interview results and the second area is the simplified design analysis presented by Baldetti and Lockard.

The purpose of the telephone interview was to assess the reasons behind the slow implementation of passive solar design guidance thoughout the Air Force. Five questions were developed. The first question was used to find the individual responsible for implementing Air Force guidance. The next four questions were aimed at assessing the individual's: 1) awareness of passive solar design techniques; 2) familiarity with Air Force guidance; 3) involvement in solar system justification process; and 4) success rate in the past of justification attempts.

The results of the interview showed that the majority of the designers contacted had some working knowledge of passive solar system techniques. But there was a prevalent lack of awareness of Air Force guidance on design methodology. Over half of the respondents had never attempted to justify the use of passive solar systems. These results confirmed two hypothesises. First, design managers need to be made aware of current Air Force guidance provided in the ETLs, and second, a method is needed so that possible passive solar systems can be identified.

The second area of review is the simplified design analysis presented by Baldetti and Lockard. The end result of the analysis was the development of a graphical tool "to assist the designer in evaluating the economic feasibility of passive solar design [Baldetti

& Lockard, 1983:7]." The methodology used to achieve this end is summarized in the following steps.

1. Calculate the building's annual heating consumption (AHC).

   AHC = SF * SFBLC * HDD

   where
   SFBLC = square foot building loss coefficient

2. Calculate the annual solar savings (ASC).

   ASC = AHC * SSF

3. Determine incremental cost of passive solar system (Cs).

4. Determine glazing area (Ac).

   Ac = Af * glazing rule of thumb

   where
   Af = heated floor area of facility

5. Determine solar add on cost (SAC).

   SAC = Ac * Cs

6. Extract fuel efficiency (E) and Uniform Present Worth (UPWF) values from appropiate tables.

7. Calculate break-even fuel cost (X) in order to determine the feasibility of a passive solar system.

   $$X = \frac{E * 0.9 * SAC}{UPWF * SSF * AHC}$$

   where
   0.9 = the Air Force guidance on allowing a 10% discount of SAC

8. These values are tabulated based on system type, fuel type, and location for easy reference.

As with any simplified procedure, there are a few qualifying assumptions. The assumptions that form the foundation for Baldetti and Lockard are presented in Figure 2.13.

1. Passive Solar Design Handbook, Volume 2, methodology.
2. Building square foot range of 2,000 to 30,000 square feet.
3. Building Budget of 9 BTU/HDD/square foot/year.
4. Reference building designs are representative.
5. Floor storage system is the same for both conventional as well as passive solar building systems (4 inches).
6. Eight-inch thick thermal storage wall used in Trombe wall system design.
7. Conventional wall systems include 15 percent window area.
8. Exclusion of operations and maintenance, slavage and replacement costs in life-cycle analysis.
9. Use of 1983 Federal Register UPWE figures for the life-cycle analysis.
10. Use of closest reference city figures for establishing solar data for the 87 bases.
11. Limiting the building length to width ratios of 1:6.
12. Use of forced air to avoid overheating where the percent area served is not achieved in actual configuration.
13. Use of low rule of thumb figures for the glazing area and the corresponding solar savings fractions.

Figure 2.13 Assumptions (Baldetti & Lockard, 1983:78)

The assumptions fail to address certain aspects of the design process -- in particular, internal heat gain, specific facility and location energy budget figures, and the relationship of conservation and passive solar systems. First, the assumption underlying the methodology in Volume II of the Passive Solar Handbook is that the procedure is limited to addressing

> smaller passive solar buildings for which the heating requirement is determined primarily by energy losses through the exterior surface of the building with only a small contribution from sources of heat inside the building such as people, lights, and equipment (Vol II,1980:2).

In essence, this statement is the driving force behind using 65° F as the base temperature in determining the DD figure. As stated earlier, if the procedure was applied to larger structures based on a inflated DD figure the passive solar system size may cause overheating and economic infeasibility.

Second, the square foot building load coefficient is assumed to be 9 BTU/DD sf yr. This assumption does not allow the economic evaluation to be facility and location specific. In that, the annual heating consumption is based on this figure and if the figure is higher than the actual annual heating consumption an unrealistic energy savings is projected. The energy savings due to a passive solar system is the basis for justifying its use.

Finally, no way is given in the methodology to balance the use of conservation and passive solar systems. As mentioned earilier, energy savings is optimized with a proper balance between the two.

This chapter has provided to the reader background information on various passive solar systems, design considerations and techniques, Air Force guidance, and Captains Baldetti and Lockard's thesis effort. Now that the reader is knowledgeable in these areas and of the energy problem in general, the next chapter's focus is to present the methodology for achieving two objectives. The first objective is to accurately assess the extent of institutionalization of passive solar design into Air Force construction. Therefore, in order to meet this objective, a telephone interview aimed at both the Major Command level and base-level design manager was designed and is outlined first in the next chapter. The second objective is to generate pertinent design and economical parameters that can communicate the Air Force desires in the project book. The second part of the methodology chapter presents a step-by-step procedure that calculates these parameters.

III. Methodology

Introduction and Purpose

The methodology used in this report is divided into two main parts. The first part assesses the following:

1. Current Air Force design manager's knowledge and understanding of passive solar techniques and related AF policy.

2. The degree supplemental guidance is provided to the design manager on the subject of passive system design and analysis techniques.

3. How the design manager translates AF specifications for passive solar systems into the Military Construction Program (MCP) Project Book.

The second part describes the process by which the passive solar system design parameters are developed. These parameters can be incorporated as line items in the architectual/structural section of the MCP project book.

Telephone Interview Questionnaire Development

The implementation of passive solar systems in new Air Force facility construction has been slow despite the existence of detailed guidance. In order to determine the factors responsible for the present situation, two survey questionaires were developed. The first survey questionaire was directed to the Major Commands. The MAJCOMs are responsible for monitoring solar applications in facility construction, and issuing supplemental guidance to their bases on the

format and required items necessary to construct an MCP project book. The second survey was directed to the design manager at base level who determines the applicability of passive solar systems for a given project, and translates the requirement into specifications contained in the MCP project booklet.

A telephone interview was selected as the survey instrument in each case for four reasons (Baldetti & Lockard, 1983):

1. Quick response time was desired.
2. The complexity of the questions required direct contact with the individual.
3. The organizational position of the individual contacted varied with the bases selected (making a mailed survey difficult).
4. Responses were desired from several Major Commands and climate regions.

Major Command Interview. The questions presented in the Major Command survey, shown in Figure 3.1, were separated into 12 basic areas. However, before starting the interview, it was necessary to locate the individual responsible for Command policy concerning solar applications and requirement specifications.

The first four interview questions were designed to indicate the respondent's familiarity and experience with solar applications and related Air Force policy. Questions were adapted from a survey developed by Baldetti and Lockard.

The first question indicated what area of building construction design (new, renovated, or both) the bases in their Major Command were involved with over the past year. If the bases were involved in both new and existing construction design, then the respondent was asked to

1) Area of construction design:
   a. New construction
   b. Renovation
   c. Both

2) Knowledge and understanding of passive solar systems:
   a. Very familiar
   b. Familiar
   c. Unfamiliar

3) Knowledge and understanding of Air Force Solar Design guidance:
   a. Familiar
   b. Unfamiliar

4) Prior involvement with solar application justification:
   a. Active only
   b. Passive only
   c. Both
   d. None

5) Method used to assess the cost effectiveness of passive solar for bases in your Command.
   a. Preliminary Feasibility Assessment provided in ETL 84-1.
   b. Analysis performed at MAJCOM
   c. Analysis performed at base-level.
   d. Other
   e. None

6) How do you determine which passive technique (i.e., daylighting and/or passive solar heating and cooling) will be considered for a given project.
   a. Analysis performed at MAJCOM.
   b. Recommendation from base-level
   c. Other

7) Areas of passive solar guidance that you provide to your bases.
   a. Feasibility per project/system selection/economic analysis
   b. Other (specify)
   c. None

Figure 3.1. Major Command Interview

8) Section of Project Booklet (PB) where passive solar system requirements are specified.
   a. Architectural/Structural
   b. Mechanical
   c. Other (specify)

9) Does MAJCOM prefer location.
   a. yes
   b. no

10) Features required in passive solar specification in PB.
   a. Standard statement of requirement.
   b. Specific Passive Solar application recommended.
   c. Anticipated/Expected energy savings in BTU's and/or dollars.
   d. Requirement for A-E to summit at least three concept sketches of passive system.
   e. Other (specify).

11) Knowledge and understanding of economic analysis for passive solar heating developed by Captains Baldetti and Lockard.
   a. Familiar
   b. Unfamiliar

Figure 3.1.(cont) Major Command Interview

estimate the percentage of involvement in each facility design type.

The second question established the respondent's awareness of passive solar system design techniques -- in particular, the distinction between active and passive solar techniques.

A question concerning the individual's familiarity with general Air Force guidance expressed in ETLs on passive solar design comprised the third question. Topic areas included normal passive solar techniques (ETL 82-6), unique passive solar techniques (ETL 82-7), and unique passive solar feasibility assessment (ETL 84-1).

The fourth question measured the respondent's degree of involvement in designing and justifying passive solar energy

application. Experience using life-cycle cost analysis was the main issue.

The next six questions focused upon the Major Command's policy and guidance in assessing, selecting, designing, and specifying passive solar systems. The intent of these questions was to indicate both the breath and depth of the Major Command's involvement in passive solar applications. In addition, these questions attempted to identify factors that explain the reason for slow implementation of passive solar in new facility construction.

Selection Process. A purposive non- probability sample was preferred over random sampling; therefore, an expert choice criteria was employed. This criteria is based on selecting those Major Commands in the best position to provide the required information. This criteria was applicable for this interview, since in the continental United States, six Major Commands are responsible for building construction on 99% of the Air Force Installations; therefore, all six were selected. They are: (1) Air Force Logistics Command (AFLC), (2) Air Force Systems Command (AFSC), (3) Air Training Command (ATC), (4) Military Airlift Command (MAC) (5) Strategic Air Command (SAC), and (6) Tactical Air Command (TAC).

Base-level Interview. The base-level telephone interview targeted facility design managers at those bases identified by the Major Commands as feasible for passive solar applications. In this interview, the intent was to gain information on how base-level designers incorporate unique passive solar considerations into the facility design process for a given project, and then specify the

resultant solar requirements into the project booklet.

Questions for the interview are shown in Figure 3.2. As in the Major Command interview, it was also necessary to locate the proper base-level design manager before beginning the interview.

The first four questions were similiar to those used in the Major Command interview. These questions provided general information about the respondent's familiarity with concepts and policies related to passive solar application. However, the first question also assisted in locating the appropriate design manager. If the individual did not acknowledge having experience with either new and/or existing facility construction design, then another respondent was solicited.

Question five was designed to indicate the manager's awareness that the base is considered feasible for unique passive solar applications.

The next three questions focused on the different design and analysis procedures used during the preliminary facility design process to assess passive solar systems. Specifically, question six targeted those methods used to assess feasibility of solar systems. The seventh question's focus was the criterion employed to determine which unique passive solar techniques (whether it be daylighting and/or passive solar heating and cooling) were most applicable for the project. Finally, question eight identified additional analysis techniques the facility designer used to formulate passive solar requirements for the project booklet.

Questions nine through eleven provided information regarding the information obtained from preliminary analyses with respect to the

1) Area of construction design:
   a. New construction
   b. Renovation
   c. Both

2) Knowledge and understanding of passive solar systems:
   a. Very familiar
   b. Familiar
   c. Unfamiliar

3) Knowledge and understanding of Air Force solar design guidance:
   a. Familiar
   b. Unfamiliar

4) Prior involvement with solar application justification:
   a. Active only
   b. Passive only
   c. Both
   d. None

5) Cost effectiveness assessment for your base:
   a. Cost effective
   b. Not cost effective
   c. Uncertain

6) Method used to assess the feasibility of passive solar for your base.
   a) MAJCOM direction
   b) In-house analysis (specify)
   c) Both
   d) None

7) How do you determine which passive solar technique (i.e., daylighting and/or passive solar heating and cooling) are most applicable for a given project at your base.
   a) MAJCOM direction
   b) In-house analysis
   c) Both
   d) Leave determination to A-E.
   e) Other (specify)

Figure 3.2. Base-level Interview

8) What kinds of preliminary analyses do you perform related to passive solar systems do you perform prior to making up the project booklet.
   a) Specify
   b) none

9) Section of PB where passive solar requirement is placed.
   a) Architectural/Structural
   b) Mechanical
   c) Other (specify)
   d) Not Considered

10) Features contained in Project Books prepared in 1984 to translate passive requirement to A-E.
   a) standard statement of requirement same in all PB. (i.e. Passive Solar may or will be considered in design phase).
   b) bottom line recommendation for or against per project and specify what passive solar techniques (i.e. daylighting and/or passive solar heating and cooling) would be most beneficial for the facility.
   c) Anticipated energy savings in BTUs and/or dollar
   d) Requirement for A-E to submit three concept sketches.
   e) Other (specify)

11) Organizational Level most responsible for specifying the passive solar system parameters included in PB.
   a) AF policy letter
   b) MAJCOM
   c) Local base-level policy
   d) Other (Specify)
   e) None

12) What improvement would you recommend to improve the present method of analysis.

Figure 3.2 (cont). Base-level Interview

project booklet (PB). The section within the project booklet where unique passive solar requirements were placed was the focus of question nine. Question ten pinpointed the amount of detail used to specify these requirements in the PB. Finally, question eleven determined the respondent's own perception of what organizational level has the most influence on the format and location of passive

solar information in the PB.

The final question was open ended and solicits the respondent to identify ways in which the present design process may be improved.

Selection Process. The objective of the selection process was to obtain a random cross-sectional sample from qualified Air Force Bases. To be considered for selection, the base had to meet three criterion. First, the base had to be located within the Continental United States. Second, the base had to belong to one of the interviewed six Major Commands. Finally, feasibility for unique passive solar applications must have been previously established IAW Air Force policy.

The final selection process ensured a random cross-sectional sample. Eligible bases were further subdivided into the four climatic regions identified in the Passive Solar Design Manual for Naval Installations. Then three bases were selected randomly from each climate region. This process was repeated until the final twelve bases contained at least one representative from each Major Command, but no more than three resprentatives. In doing so, all interviewed Major Commands were represented, but no one Command dominates the data collection. The final installations selected are shown in the Figure 3.3.

Design Parameter Development

This section composes the second part of the methodology chapter and discusses the development of pertinent parameters that are essential in the designing of a passive solar system.

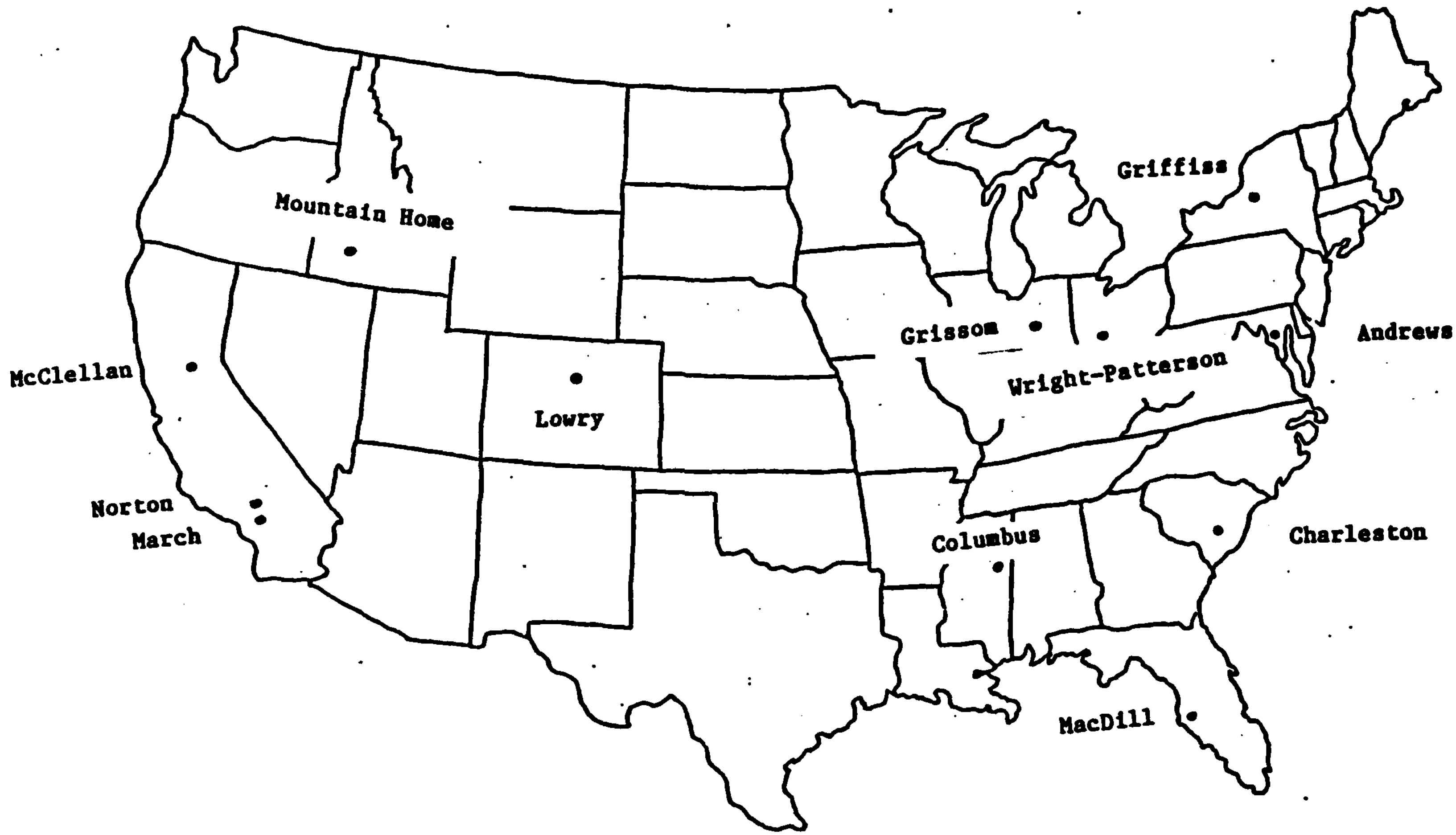


Figure 3.3. Selected Bases

The approach discussed considers such factors as building size, insulation levels, solar glazing size, conductance and absorptance, and geographical location. The results of this methodology give an estimate of yearly auxiliary heat requirement's from which energy savings are calculated and represented either in units of dollars or BTU's.

Generalized guidance to estimate energy savings is presented to the MAJCOM in ETL 84-1. However, a method is not available at the base-level that allows the design manager to refine these estimates and determine what passive solar system should be recommended to the design A-E on a per project basis. The base-level design manager could take the work of Baldetti and Lockard and, based on fuel cost at the location, get an indication as to what passive solar systems are economically feasible. The problem arises in that Baldetti and Lockard's methodology is not being employed at the present time. Yet, even if their work was incorporated into Air Force procedure, several limitations exist that may detract from full implementation -- such as, the restriction to single story residential, small commercial buildings. These limitations are due mainly to the cost figures used in their methodology and the assumption made on internal heating loads. That is, the internal loads are considered small which increases the degree day calculation used in determining the building heat load calculation. The degree day and building heat load calculation are discussed later in this chapter.

Based on the procedures established in the <u>Passive Solar Design Manual for Naval Installations</u>, this methodology provides

the base-level design manager with an easy and systematic method to determine design parameters -- such as, insulation levels and solar glazing area -- and economic parameters -- such as, energy saved and a savings to investment ratio (SIR) -- that are system dependent. These parameters can be easily transferred to line items in a project book, thereby setting target figures for the A-E.

Approach. The design process and economic evaluation of passive solar systems can be divided into three distinct phases. The first phase requires the sizing of the solar glazing area and insulation levels based on rough estimates of the building's dimensions and location.

The second phase produces a solar savings figure and has several steps. The first step requires a calculation for a building load coefficient based on the information attained in the first phase. In the second step, the design manager chooses a reference passive solar system. The bases of the choice could be a system's construction that most closely approximates normal construction methods. This criteria helps in maintaining a low passive solar system incremental cost. Once a system is chosen for evaluation, the design manager can read and record the performance correlation parameters from tables provided in Appendix F. Also, in this second step a method is provided for the integration of mixed systems. The third step presents a way for determining a facility's heating degree days on a yearly bases. The heating degree day is then used in the fourth step to calculate the yearly heat requirement of the facility (Qaux). The heating requirement is expressed as BTU's and is based on the incorporation of

the passive solar system and the recommended insulation levels. The fifth step calculates the facility heating requirement based on normal construction (Qnorm) without the use of passive solar systems. Finally, the difference in Qnorm and Qaux is the solar savings acquired from the use of the insulation levels and the passive solar system.

The third phase of the methodology generates a savings to investment ratio (SIR). First in this phase, the method used to determine a solar system's incremental cost is discussed. This cost represents the investment made by the Air Force in the passive solar heating system. In order to calculate the SIR, the solar savings from phase two is divided by the incremental cost of the system.

The results of the methodology -- in particular, insulation levels, solar glazing size, system type, solar savings, and SIR -- can be recorded as line items in the MCP project booklet.

Guidelines for Insulation Levels and Solar Collector Area. The guidelines presented in this section provide the building design manager with starting-point values for levels of insulation and solar collector area in passive solar buildings. The purpose of the guidelines is to achieve good passive solar design by balancing conservation and solar gains. Proper balance depends on local solar and weather characteristics.

Insulation Levels. Recommended levels of insulation take into account the particular climate region in which the building is located and the building size. Following the guidance in the Passive Solar Design Manual for Naval Installations, R-values

(thermal resistance) of wall insulation should fall within the interval shown below:

Mild Region: $Rwall_o = 10$ to 15
Moderate Region: $Rwall_o = 15$ to 20
Harsh Region: $Rwall_o = 20$ to 25
Very Harsh Region: $Rwall_o = 25$ to 30

These recommended wall insulation levels apply to small residential building -- in particular, a 1500 square foot, one-story, single-family detached residences -- and are based on the location's climatic region from figure 2.11 (Wray, 1983). The reference intervals are listed for the 86 Air Force installations in the Continental United States in Appendex E.

Large buildings -- such as dormitories, service clubs, office buildings and two-story, single-family residences -- require less insulation. During the winter, these buildings make more effective use of incidental heating by internal sources because of the reduced external surface area relative to the heated floor area. The following formula computes the scaled down R-values for wall insulation (Wray, 1983):

$$Rwall = 1/3\ (Ae/Af)\ Rwall_o \qquad (11)$$

where

Ae = external surface area of the building
Af = heated floor space of the building

The remaining values for insulation levels in the building can be computed directly from the scaled wall R-value using the following formulas (Wray, 1983):

$$Rroof = 1.5\ Rwall \quad (12)$$
$$Rperim = 0.75\ Rwall \quad (13)$$
$$Rbase = 0.75\ Rwall \quad (14)$$
$$Rfloor = 0.5\ Rwall \quad (15)$$

where

Rroof = R-value for ceiling/roof area
Rperim = Insulation around perimeter of the floor in slab-on-grade construction.
Rbase = Insulation around walls of either a heated or fully bermed basement.
Rfloor = R-value of insulation for floors of heated space over unheated areas such as vented crawl spaces or unheated basements.

Solar Collection Area. The guidelines used in sizing the solar collector area are based on annual productivity. Annual productivity is defined as the "amount of useful solar heat delivered to the building by one square foot of collection aperature during a full heating season [Wray, 1983:22]." By using annual productivity to size the solar aperature the resultant passive solar system is smaller and more efficient than one sized for greater absolute energy savings using larger aperatures. The approach used in this report, of emphasizing high productivity rather than absolute energy savings, should result in a more cost effective passive solar system design.

Guidelines for sizing the solar collector area are presented in the Passive Solar Design Manual for Naval Installations for direct gain and trombe wall systems. An upper and lower ratio of solar collection area to floor area in percent is shown on a contour map of the continental United States (Fig. 3.4). Limits for the 86 Air Force bases in the Continental United States were extracted from the contour map and listed in Appendix E.

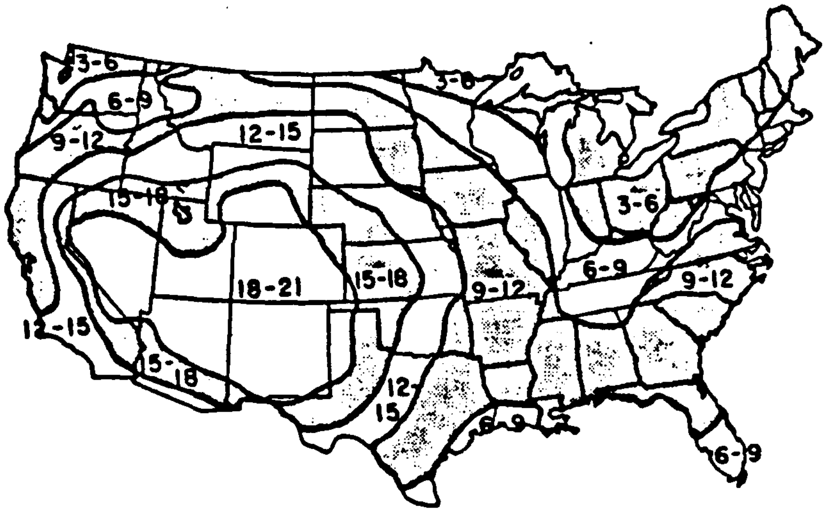


Figure 3.4. Solar Collector Area/Floor Area Ratio
(Wray,1983:24)

The figures appearing on the map in Figure 3.4 and in Appendix E pertain to the same type of small residential buildings as identified in the previous section. Therefore, for larger facilities, the ratio of collector area to floor area (Ac/Af) should be scaled down according to the following formula (Wray, 1983):

$$Ac/Af = 1/3\ (Ae/Af)\ (Ac/Af)o \qquad (16)$$

where

Ae = external surface area of the building
Af = heated floor space of the building
(Ac/Af)o = reference value of collector-area-to-floor area ratio from contour map.

Therefore

$$Ac = (Ac/Af) * Af \qquad (17)$$

Design Analysis. Using the guidelines in the previous section to specify initial values for insulation and solar collection area, the designer now analyzes the passive solar performance of the building. The procedures presented in this second phase of the design process provide a simple means for determining the annual solar savings by comparing the auxiliary heating requirement of the passive solar building with that of a building constructed without a passive solar heating system. The first step in the process is to obtain an estimate of the building's thermal load and is expressed as the building load coefficient.

Building Load Coefficient (BLC) Estimation. In this section, a simple procedure is outlined for estimating the building load coefficient and uses general infommation about the building. The BLC provides a measurement of how effectively a building is sealed and insulated to reduce infiltration and heat loss by conduction through its nonsolar elements (Wray,1983). The methodology consists of summing together several estimated contributions of heat loss. It is based on formulas presented in Volume II of the Passive Solar Design Handbook.

The first step is to make a rough estimate of the combined area of all heated floors (Af) and the total external perimeter (Pt). This perimeter the combined length of all external walls of all floors in feet. Next, estimate the combined area of all east, west, and north windows by either one of the following methods:

1. A rough estimate by the exterior building designer or

2. Use the formula (Wray, 1983):

$$An = (Pt * h - As) * NSF \qquad (18)$$

where
An = square feet of nonsouth window area
h = ceiling height in feet
As = total area in square feet of the south wall and includes the solar collector area (Ac)
NSF = nonsouth window fraction (window area divided by wall area)

Suggested values of NSF for each climate region are based on the guidance in ETL 82-6 and presented below:

1. Mild and Moderate Regions: NSF = 0.10
2. Harsh Regions : NSF = 0.07
3. Very Harsh Regions : NSF = 0.05

In the third step, compute the heat loss due to various building components using the following formulas:

1. Walls

$$Lw = 24\ Aw/Rwall \qquad (19)$$

where

$$Aw = (Pt * h) - An - Ac$$

2. Nonsouth window

$$Ln = 26\ An/NGL \qquad (20)$$

where
NGL = the number of glazings on nonsouth windows

3. Choose the one which pertains to your building

   a. Perimeter (slab-on-grade construction)

$$Lp = 100\ Pg/(Rperim + 5) \qquad (21)$$

   where
   Pg = external perimeter of the ground floor in feet

b. Floor over vented crawl space
$$Lf = 24\ Ag/Rfloor \tag{22}$$

where
Ag = square feet area of the ground floor

c. Basement (heated basement or other fully bermed wall and includes floor losses)
$$Lb = 256 * Pg/(Rbase + 8) \tag{23}$$

4. Roof
$$Lr = 24\ Ar/Rroof \tag{24}$$

where
Ar = area of the roof projected on a horizonal plane

5. Infiltration
$$Li = 0.432 * ACH * ADR * h * Af \tag{25}$$

where
ACH = average number of air changes per hour
ADR = Air Density Ratio; it accounts for other-than-sea-level locations and is obtained from Figure 3.5.

Finally, the BLC is obtained by adding together the heat loss contributions from each building component. BLC is expressed in units of BTU/^{o}F day.

$$BLC = Lw + Ln + (Lp \text{ or } Lf \text{ or } Lb) + Lr + Li \tag{26}$$

Passive Solar System Selection. The second step in the design analysis phase is to select a reference passive solar system. Unfortunately, no method presently exists for helping the building design manager choose the "best" passive solar system. Generally, the selection process is influenced by a variety of considerations -- such as, building security, summer cooling loads, minimizing overheating or severe temperature swings and architectural compatibility with the base. In the absence of a single fool-proof method, general guidance

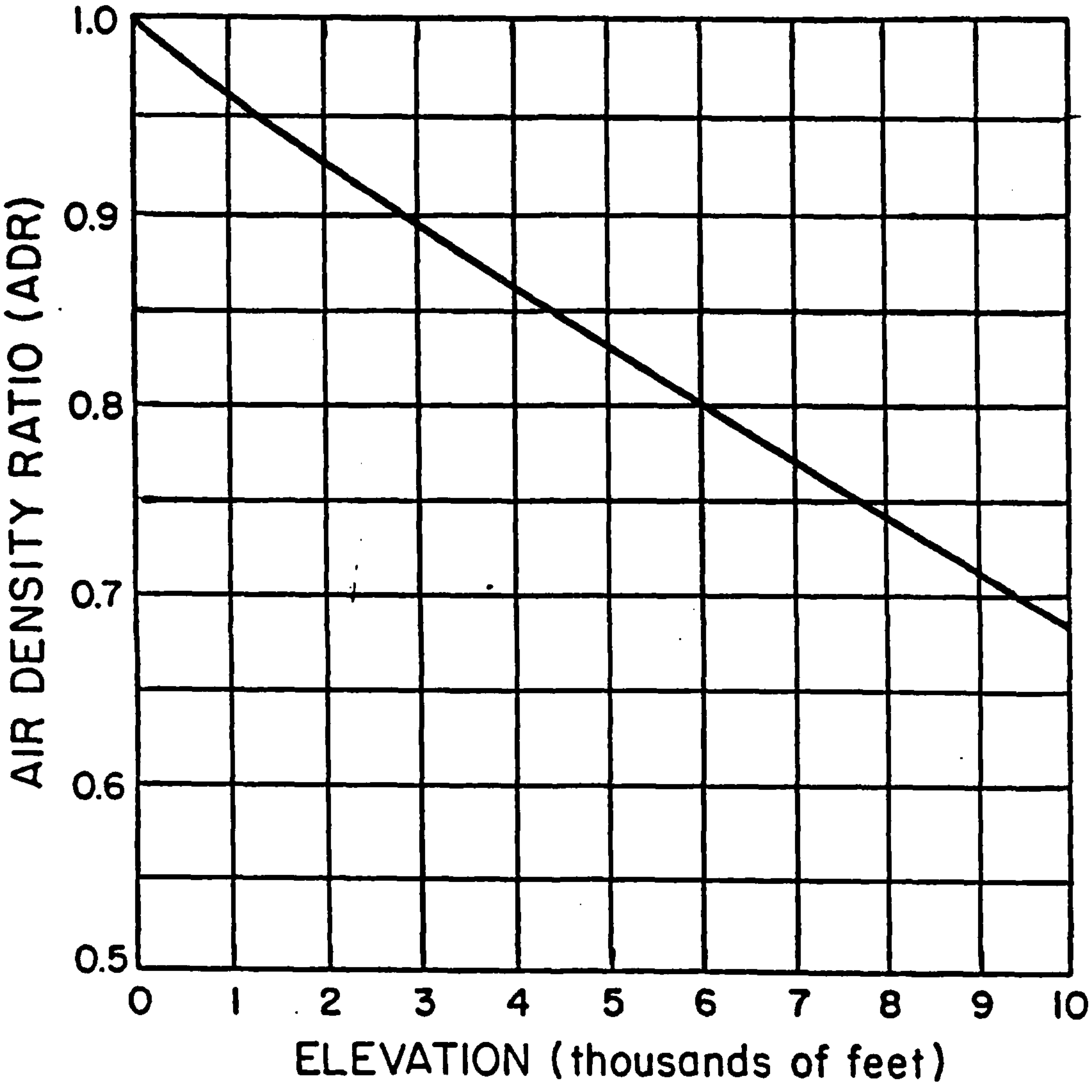


Figure 3.5. Air-Density Ratio (ADR)
(Wray, 1983: 35)

is presented below for each of the four climate region from the <u>Passive Solar Design Manual for Naval Installations</u>.

1. Mild Climate Region. In this region the winter heating load varies from small to nil and can be met using less expensive direct gain systems with relatively small solar collection aperatures.

2. Moderate Climate Region. Both thermal storage wall and direct gain systems are appropiate in this region.

3. Harsh Climate Region. Both thermal storage wall and direct gain systems are appropiate in this region. Night insulation should be considered with direct gain systems at the northern extremes of this region.

4. Very Harsh Climate Region. Thermal storage walls are preferred and the addition of night insulation may be advisable near the northern boundary of this region. Near the boundary between the harsh and very harsh regions or in areas with greater than average sunshine, direct gain systems without night insulation may still be viable but only if the collection aperature is kept fairly small.

Additional recommendations for glazing levels for thermal storage walls (Table 3.1) and direct gain systems (Table 3.2) with or without night insulation are presented for the four climate regions. Defensive strategies for controlling summer heat gains are also suggested.

<u>System Correlation Parameter Selection.</u> The next task is to select the system correlation parameters that most closely corresponds to the proposed system design. In this section guidance for that selection process is provided.

Table 3.1 (Wray, 1983:20)

Recommended Glazing Levels for Thermal Storage Walls

(no night insulation)

Climate	No. of Glazings	Defensive Cooling Strategy
Mild	1	External covers
Moderate	1-2	External covers
Harsh	2	Seasonal overhang and venting
Very Harsh	2-3	Fixed overhang and venting

(with night insulation)

Climate	No. of Glazings	Defensive Cooling Strategy
Mild	1	Seasonal Cover
Moderate	1	Seasonal Cover
Harsh	1-2	Seasonal Cover
Very Harsh	2	Seasonal Cover

Table 3.2 (Wray, 1983:20)

Recommended Glazing levels for Direct Gain Systems

(no night insulation)

Climate	No. of Glazings	Defensive Cooling Strategy
Mild	2	External covers
Moderate	2	Internal shades or blinds
Harsh	2-3	Drapes and seasonal overhang
Very Harsh	3	Drapes and fixed overhang

(with night insulation)

Climate	No. of Glazings	Defensive Cooling Strategy
Mild	1	Seasonal cover
Moderate	1-2	Seasonal cover
Harsh	2	Seasonal cover
Very Harsh	2-3	Seasonal cover

Tables of system correlation parameters for 109 passive solar designs are included in Appendix F. These values were extracted from Appendix A of the <u>Passive Solar Design Manual for Naval Installations</u>.

Steps in the selection process are listed below.

1. Choose the type of passive solar heating system using the guidance provided in the preceding section; the types of passive solar system are:

   a. Direct Gain Systems
   b. Trombe Wall vented and unvented.
   c. Water Wall
   d. Concrete block walls, thermal storage walls constructed of 8 inch x 8 inch x 16 inch concrete building blocks, with or without mortar filling in the cores.

2. Identify and select the values for each of the four principle design variables. These variables define a reference system. The principle design variables and associated values for each system type are shown below:

   a. Direct Gain (81 reference systems)
      Am/Ac = 3, 6, or 9
      THICK = 2, 4, or 6 (in)
      Rvalue = 0, 4, or 9 (h ^{o}F sf/BTU)
      NGL = 1, 2, or 3

      where
      Am/Ac = ratio of mass surface area to solar collection area.
      THICK = thickness of the thermal storage mass in inches.
      Rvalue = R-value of night insulation

   b. Trombe Walls (18 reference systems)
      THICK = 6, 12, or 18 (in).
      PCK product = 15 or 30
      (BTU squared/h sf ^{o}F squared)
      Rvalue = 0 or 9 (h ^{o}F sf/BTU)
      NGL = 1 or 2

where
PCK product = product of density, specific heat and thermal conductivity of the thermal storage mass.

c. Water Walls (6 reference systems)
THICK = 6, 9, or 12 (in).
Rvalue = 0 or 9 (h ^{o}F sf/BTU)
NGL = 1 or 2

d. Concrete Block Walls (4 reference systems)
MORTAR = filled or unfilled
NGL = 1 or 2

3. Locate the appropriate reference system using the system numbering procedure described at the beginning of the parameter tabulation appendix.

4. Finally, read the system correlation parameters from the table. These parameters are:

F = scaling factor for solar load ratio
G = effective loat coefficient of the solar aperature per square foot.
Uc = steady-state aperature conductance
α = effective solar absorptance

The rules of thumb presented in Table 3.3 should help the designer select initial values for the principle design variables in direct and trombe wass systems. These rules were developed from various research findings presented in Volumes II and III of the Passive Solar Design Handbook.

Mixed systems combine several, usually two, distinct passive solar heating systems in one building design. Correlation parameters for mixed systems are obtained by weighting the parameters of the component systems by the relative proportions of their respective collection areas.

Table 3.3

Rules of Thumb for Principle Design Variables

Direct Gain Systems

Climate	Am/Ac	THICK	R-value	NGL
Mild/moderate	6	4	0-4	1-2
Harsh	6	4	4-9	2
Very Harsh	6	4	9	2-3

Trombe Wall System

Climate	THICK	Pck	R-value	NGL
Mild/Moderate	12	30	0 or 9	1-2
Harsh	12	30	9	2
Very Harsh	12	30	9	2

Note: Vented trombe wall systems should only be considered in very harsh climates and/or with thermal wall thickness of 18 inches.

A complete description of the properties of the direct gain, trombe wall and water wall reference designs is presented in Table 3.4.

Weather Parameters. Having determined the BLC and passive system parameters (F,G,Uc and α), the next step is to obtain the site specific weather parameters. These weather parameters are the transmitted radiation-to-degree-day ratio, VT/DD, the city parameter "a" and the yearly heating degree days (DDy). A step-by-step procedure is listed below to obtain the required parameters:

Table 3.4 (Wray, 1983:39)

Reference Design

Masonary Properties (direct gain and Trombe wall)	pck = 15	pck = 30
thermal conductivity (k)	0.6 Btu/h ft ^{o}F	1.0 Btu/h ft ^{o}F
density (p)	125 lb/ft^3	150 lb/ft^3
specific heat (c)	0.2 Btu/lb^{o} F	0.2 Btu/lb ^{o}F

Solar Absorptance of thermal mass	
water wall	0.95
Trombe wall and concrete-block wall	0.95
direct gain	0.80
Infrared emittances of thermal storage mass	0.90
Glazing properties	
transmission characteristics	diffuse
orientation	due south
index of refraction	1.526
extinction coefficient	0.5/inch
thickness of each pane	1/8 inch
air gap between panes	1/2 inch
Control range	
room temperature	65^{o} F to 75^{o} F
internal heat generation	0
Termocirculation vents (vented Trombe walls)	
(when used)	
vent area/Trombe wall area (sum of both upper and lower vents)	0.06
height between vents	8 ft
reverse flow	none
Night Insulation	
(when used)	
thermal resistance (thermal storage walls)	R9
thermal resistance (direct gain)	R4 or R9
in place solar time	0530 - 0730
Solar radiation assumptions	
shading	none
ground diffuse reflectance	0.3

1. Locate the reference city nearest to the proposed building site. Weather parameters for 209 cities within the Continental United States from Appendix B of the Passive Solar Design Manual for Naval Installations are included in Appendix G of this thesis. In addition, the closest reference city for each of the 86 Air Force bases and operating locations is listed in Appendix E.

2. Calculate the base temperature (Tb) for the building using the following equation:

   $$Tb = Tset - Qint / (NLC + 24 * Uc * Ac) \quad (27)$$

   where
   Tset = thermostat set point temperature (68^{o} F by DoD Regulation)
   Qint = internal heat generation rate (BTU/day); a general estimate of Qint can be obtained by multiplying the estimated number of occupants of the building by heat generation rate of per person (20,000 BTU/day).

3. Finally, locate the weather parameters in Appendix G corresponding to the base or reference temperature calculated above Reference temperatures range from 40^{o} to 70^{o} F in 5^{o} F increments. Values for VT/DD are labeled VT1/DD, VT2/DD, or VT3/DD depending on whether the system of interest is single, double, or triple glazed. City parameter "a" and DDy are also obtained from the same column as VT/DD. For mixed systems with difference numbers of glazings, calculate an area weighted glazing by usings

   $$NGL = (Ac1 * NGL1 + Ac2 * NGL2)/(Ac1 + Ac2) \quad (28)$$

   The values for ratio VT/DD and city parameter "a" are then obtained by interpolating between the appropriate integral values in the column.

Auxiliary Heat Requirement (Qaux) Estimation. Now, the annual auxiliary heating requirement of the passive solar building is calculated by the procedure presented in the Passive Solar Design

Manual for Naval Installations and outlined below. This figure represents the amount of heat that must be supplied by the mechanical heating system per heating season in order to maintain a 68° F set-point temperature.

1. Calculate the scaled solar load ratio (SLR*) of the system

   SLR* = F * [(Vt/DD) * α /(BLC/Ac + G)] (29)

2. Determine the yearly heat-to-load ratio (Qaux/Qload)y from the nomogram in Figure 2.12 using the calculated SLR* and city parameter "a".

3. Obtain Qaux as follows:

   Qaux = (Qaux/Qload)y * (BLC + G * Ac) * DDy (30)

   where
   Qaux is normally expressed in units of MBTUs (one million BTUs)

Nonsolar Heat Requirement (Qnorm) Estimation. In this section, the building designer calculates the heating requirement of a building constructed without passive solar and IAW present Air Force standards for insulation levels. The procedure listed below is designed to give a "quick and dirty" estimate of Qnorm.

1. Calculate the building load coefficient for the nonsolar building (BLCnorm). Refer to ETL 83-9 (Appendix D) for the maximum transmission values, U-values, for Air Force facilities. To locate the proper U-values (Uo, Ur, Uf), use the DDy from previously recorded weather parameters. BLC norm is compute as follows:

   a. Determine gross wall heat loss, Lwo.
      Lwo = 24 * Pt * h * Uo (31)

where
Uo = gross wall U-value (the effective heat loss from opaque walls, windows, and doors)

b. Determine heat loss through the roof.

$$Lr = 24 * Ar * Ur \qquad (32)$$

c. Determine heat loss by either:

1) Perimeter (slab or grade)

$$Lp = 100 * Pg/(Rperim + 5) \qquad (33)$$

where
$Rperim = 1/Uf$
Uf = Uf value for slab-on-grade floor

or:

2) Floor (over vented crawl space)

$$Lf = 24 * Ag * Uf \qquad (34)$$

where
Uf = Up value corresponding to heated floor over unheat floor space

d. Retrieve value of infiltration loss (Li) from previous BLC calculation

e. Calculate BLCnorm by the formula:

$$BLCnorm = Lwo + Lr + (Lp \text{ or } Lf) + Li \qquad (35)$$

2. Compute Qnorm by multiplying BLCnorm by the annual heating degree days (DDy)

$$Qnorm = BLCnorm * DDy \qquad (36)$$

<u>Annual Solar Savings Calculation.</u> Having previously determined the annual heating requirement for a passive solar building (Qaux) and a nonsolar building (Qnorm), the annual solar savings (SS) is determined by subtracting Qaux from Qnorm.

$$SS = Qnorm - Qaux \qquad (37)$$

The annual solar savings represent the amount of energy that is saved, 'n BTUs, using a particular reference passive solar system. In

order to determine the solar savings from a different reference system, Qaux is recalculated after the appropriate adjustments are made in the system parameters (F,G,Uc, and α) and possibly the weather parameter (VT/DD).

Economic Analysis. In this third phase of the methodolgy, a determination as to the economic feasibility of passive solar systems is made. Therefore, a procedure to assess the system cost differential of passive solar systems, referred to as the solar add-on cost (SAC), is presented first so as to complete the list of required data needed to calculate the savings to investment ratio (SIR). Second, since all the required data is available, the SIR methodology is covered.

Passive Solar System Incremental Cost. The next major part is to determine the cost difference between a building using passive solar heating and one constructed conventionally. The objective is to establish unit costs for different passive solar and conventional building designs. This approach enables the design manager to quickly estimate the solar add-on cost for his particular project.

Since the solar add-on cost (SAC) for a particular facility depends on the type of passive solar and conventional design, the size of the passive system, and site location, the effects of these variables are considered. In estimating the solar add-on cost, a four-step approach was used: 1) estimation of unit cost for different reference passive solar designs (Csol) expressed in terms of cost per square foot of solar collection area (\$/Ac); 2) estimation of unit

cost for different conventionally constructed facilities (Cnorm) in terms of cost per square foot of south wall area ($/As); 3) determination of the system differential costs, SDC, by multiplying the difference between Csol and Cnorm by the solar collection area [SDC = (Csol - Cnorm) Ac]; and 4) calculation of the solar add-on cost by applying, the appropriate cost factor adjustment for your local area.

Cost data for all systems were derived from the 1984 editions of the Means Building Construction Cost Data and the Means Systems Costs Handbook. Meanwhile, cost adjustment factors, known as the city cost index, were extracted from the latter publication. City cost indexes corresponding to the 86 Air Force installations are provided in Appendix H.

Estimating Passive Solar System Costs. Estimations of cost per square foot of solar collector area were required for the reference solar designs in Appendix F. The estimation process consisted of two major parts. First costs per square foot were obtained for the principal design variables for the different passive solar system types. Second, in order to achieve the final unit costs, these variable costs were then weighted as a function of solar collector area for each reference design.

Only direct gain, vented and unvented trombe wall, and concrete block wall systems were economically evaluated in this report. Water trombe wall systems were excluded from considerations but, system parameters are included in Appendix F. By taking this approach, water walls can easily incorporated into the economic evaluation process at

a later date when more accurate costing information is available.

The solar collector system consisted of glazing panels that were 3 feet wide and 6 feet eight inches high. These panels were constructed of either single or double glazing with 3/16 inch thick panes. These panes differ from the reference system in Table 3.4; however, the discrepency is not considered to have a significant impact on the system performance. Triple glazed direct gain systems were not considered for economic reasons.

Masonry walls and floors provided thermal storage for the direct gain systems. Solid reinforced concrete blocks were chosen for the reference interior wall partitions. For the thermal floor, reinforced light industrial concrete slab on grade floors were selected. Economic analysis was confined to storage systems thicknesses of either four or six inches. Two inch thick masony walls and floors were considered impractical for most Air Force facilities.

For night insulation, a multi-layered mylar sheet with heat reflective coating and metal roller was chosen. R9 insulation level is achieved by using three layers of mylar. Whereas, a double layered mylar shade provided an insulation level of R4. Unit costs for the particular direct gain design variables are shown in Table 3.5.

Major cost elements for trombe wall designs include collector glazing panels, thermal storage wall, venting system, and night insulation.

The collector glazing system for trombe walls is similar to the direct gain system. Both were adopted from reference systems in the Means Systems Cost Handbook.

Table 3.5

Direct Gain Material Costs

Element	Design Variable	Cost Per Square Foot
Glazing Panel	single - glazing	$14.63
	double - glazing	$18.45
Thermal Wall	4 inch	$ 3.91
	6 inch	$ 4.42
Thermal Floor	4 inch	$ 2.68
	6 inch	$ 3.30
Night Insulation	R4	$ 5.05
	R9	$ 5.81

In addition, glazing panels are available in fixed panel dimensions of six feet, eight inches high and three feet wide, and contain either 3/16 inch thick single or double glazed panes.

Reinforced cast in place concrete walls were used for trombe thermal storage. Wall height was fixed at eight feet, while wall thicknesses were either six, twelve, or eighteen inches. Since the masonry walls were composed of regular weight concrete (concrete density of 145 pounds per cubic foot), only trombe wall systems with high thermal storage capacity (pck=30) were considered.

The venting system consisted of vents at the top and bottom of the thermal storage wall. The top vents were operable multilouvre registers measuring six inches high and thirty inches wide. The lower vent, also six inches by thirty inches, employed a manual back draft damper to prevent reverse thermocirculation at night.

The R9 night insulation system was identical to the one used in the direct gain case.

The component material costs for trombe wall systems are summarized in Table 3.6 below.

Table 3.6

Trombe Wall Material Costs

Element	Design Variable	Cost Per Square Foot
Glazing Paned	single - glazing	$12.94
	double - glazing	$18.94
Trombe Wall	6 inches	$ 8.91
	12 inches	$10.70
	18 inches	$12.50
Venting		$27.10
Night Insulation	R9	$ 5.81

A concrete block wall system is identical to the unvented trombe wall except for the composition of the thermal storage wall. As the name implies, concrete block thermal wall is constructed of reinforced concrete building blocks measuring 8 inches by 8 inches by 16 inches, whereas the trombe wall uses solid masonry. Concrete building blocks were divided into two categories: 1) blocks with two hollow rectangular cores, or 2) blocks with mortar filling in the cores. Except for the thermal wall, the concrete block wall system contains the same glazing and night insulation employed in the unvented trombe wall system. System components and their respective costs are shown the Table 3.7.

Table 3.7

Concrete Wall Material Costs

Element	Design Variable	Cost Per Square Foot
Glazing Panel	single - glazing	\$12.94
	double - glazing	\$18.98
Concrete Blocks	hollow	\$ 4.86
	mortar filled	\$ 7.54
Night Insulation	R9	\$ 5.81

Conventional System Costs. Systems for exterior walls, interior wall partitions, windows and floors corresponding to typical Air Force construction practices were previously identified by Baldetti and Lockard. These systems were adopted for this report and are described briefly in this section.

Three exterior wall systems of different compositions were identified. The first exterior wall system consisted of four inch brick veneer supported by 3 and 5/8 inch metal studs. The walls were insulated to an R11 value with 3 and 1/2 inch fiberglass. Finally, gypsum drywall provided the finish for the interior of the wall system.

Split ribbed concrete blocks of four inches thickness comprised the second exterior wall system. This system retained the 3 and 5/8 inch metal stud support, R11 fiberglass insulation, and gypsum board interior finish from the first system.

The last conventional wall system chosen was a framed metal siding wall with steel frame support. Unlike the other two system, only R10 wall insulation was used.

For the interior wall partitions, gypsum board facing enclosed the 3 and 5/8 inch metal stud construction. These walls contain no insulation.

The reference window system was defined as double glazed insulating galss with 3/16 inch thick panes and housed in tubular aluminum framing.

Finally, the conventional floor system was composed of reinforced light industrial slab on grade concrete and is four inches thick. This system is identical to the four inch thick thermal storage floor used in the direct gain solar systems.

Cost data for the conventional system were revised using the 1984 editions of the Means Building Construction Cost Data and Means Systems Costs Handbook. These costs per square foot are shown in Table 3.8.

Table 3.8

Conventional System Material Costs

Element	Cost per Square Foot
Brick Wall	$11.50
Block Wall	$ 9.08
Metal Wall	$ 7.86
Floor	$ 2.68
Partition	$ 2.18
Window	$18.25

Calculating Csol and Cnorm. Having determined unit cost figures for passive and conventional systems design variables, the next step obtains a unit cost per square foot of collector area for the passive solar system (Csol) and a unit cost per square foot of

south wall area for conventional systems (Cnorm). This is accomplished by summing the weighted unit cost of the applicable system components. The weighting equations used to calculate Csol and Cnorm depend upon whether a direct gain or an indirect (trombe wall or concrete block wall) system is being evaluated.

Csol for direct gain systems accounts for the costs of collector glazing area, thermal storage, and night insulation. It is important to note that thermal storage costs also depend on thermal storage mass to collector area (Am/Ac) and the relative distribution of the thermal mass between the wall and floor areas. By using the unit cost figures from Table 3.5, Csol, for direct gain systems, is calculated using the following equation:

$$Csol = Cac + (Am/Ac) * (TFF * Cfloor + TWF * Cwall) + Cni \quad (38)$$

where

Cac = unit cost of glazing panel
Cfloor = unit cost of storage floor
Cwall = unit cost of storage wall
Cni = unit cost of night insulation
TWF = thermal wall fraction
TFF = thermal floor fraction

In order to measure thermal storage mass distribution, the concepts of thermal wall fraction (TWF) and thermal floor fraction (TFF) were developed. TWF is defined as the thermal wall surface area divided by the total thermal mass surface area (Am). Likewise, the TFF is the thermal floor surface area divided by Am. These fractions are based on two assumptions. First, the thickness of the thermal storage walls and floors are always equal. Second, the walls and floor represent the only thermal storage mediums, that is, TWF plus

TFF equals one. It should be noted that high values of TWF optimize the heat exchange between the thermal storage medium and living space. However, this benefit is off set by an increase in solar add-on cost. Solar and normal costs for reference direct gain systems are tabulated in Appendix I for TWF values of 0.0, 0.25, 0.50, 0.75, and 1.0.

Cnorm for direct gain systems is determined by the following equation using the cost data from Table 3.8:

$$\text{Cnorm} = \text{Cext} + \text{SWF} * \text{Cwind} + (\text{Am}/\text{Ac}) * [\text{TFF} * \text{Cfloor} + \text{TWF} * \text{Cint}] \quad (39)$$

where

Cext	=	unit cost of exterior wall
Cwind	=	unit cost of windows
SWF	=	south window fraction (south window area divided by south wall area)
Cfloor	=	unit cost of conventional floor
Cint	=	unit cost of interior wall (partition)

The Csol and Cnorm calculations for trombe wall or concrete block wall systems consider the costs of collector glazing, thermal storage, venting system, and night insulation. By referring to Tables 3.6, 3.7, and 3.8, Csol and Cnorm are determined by the equations given below.

$$\text{Csol} = \text{Cac} + \text{Cmass} + 0.06 * \text{Cvent} + \text{Cni} \quad (40)$$

$$\text{Cnorm} = \text{Cext} + \text{SWF} * \text{Cwind} \quad (41)$$

where

Cmass	=	unit cost of thermal storage wall
Cvent	=	unit cost of venting syste
0.06	=	reference vent area-to-Trombe wall area specificed in Table 3.4

<u>Savings to Investment Ratio (SIR).</u> The SIR relates the energy savings from the addition of the passive solar system and the associated conservation measures to the increased cost of construction due to the passive solar system. The increased cost is referred to in the previous section as solar add-on cost. Also, the energy savings is represented by the difference in the Qnorm and Qaux, calculated in phase two of the design analysis, times a uniform present worth factor (UPWF) for the desired location. These factors are provided by the DOE in ETL 84-1. Since the energy savings are an annually recurring cost, the UPWF is needed to determine the present worth of the energy savings accounting for discount and escalation rates over the allowable 25 year payback period. The <u>National Bureau of Standards Handbook 135</u> on life cycle costing provides the guidance as to how the SIR is defined and is presented in the following formula:

$$SIR = (E + M)/(I - S + R) \qquad (42)$$

where (all variables in units of dollars)

E = Energy saving
M = Savings in Operation and Maintenance (O&M)
I = Solar add-on cost * allowable discount rate
S = Salvage value of system
R = Differential replacement cost

In the formula, several variables are eliminated. First, since the introduction of Air Force guidance is relatively new and historical data is needed to accurately predict the reduction in O&M cost due to the passive solar system, the O&M savings are disregarded. By disregarding the O&M savings, the evaluation is actually pessimistic toward the passive solar system since the introduction of the savings would increase the size of the numerator. Second, as per

NTBS 135 guidance, the salvage value and replacement cost of a passive solar system are also disregarded for solar systems unless "more definitive information is available [NTBS, 1980:98]." Therefore, the SIR formula reduces to the following:

$$SIR = E/I \tag{43}$$

where

E = ((Qnorm - Qaux) * UPWF * fuel cost/fuel efficiency)
I = (SAC * 0.9)

In this methodology, only the energy savings due to reduced heating fuel cost are considered.

If the SIR is greater than one, then the investment is considered cost effective. Air Force guidance is to design any passive solar system that achieves an SIR greater than one to the 35% design phase. At this time other factors are considered in determining whether or not to proceed with the design to include the passive solar system -- such as, architectural compatibility.

This chapter has been presented in two parts. The first part explained the telephone interview process, and the second part described the development of the passive solar system's design and economic parameters. The next chapter follows the same basic approach. In that, the results of the interviews are analyzed first, followed by examples of calculating the paramenters using the methodology outlined in this chapter. These examples show further detail in determining the system's design and economic parameters.

IV. Analysis

Telephone Interview

First, in accordance with the selection methodology, the six major commands were contacted at headquarters level. Then, with information attained from these contacts, a total of 12 base-level Civil Engineering organizations were contacted. However, organizations did not include representatives from Systems Command. This exclusion was due to the fact that Systems Command had not completed its feasibility assessment in compliance with ETL 84-1 at the time of the interviews. These bases account for only 8 out of the 86 conus installations.

Major Command Results. The individuals contacted at the command level were those responsible for reviewing the project booklets submitted by the base for proposed MCPs. They ensure proper inclusion of solar energy considerations per Air Force guidance. In this regard, all the individuals were involved in construction design, both new and renovations. The extent of involvement in each is dependent upon the success the DOD experiences obtaining a favorable budget from Congress. More money generally means more new construction and pushes the percentage in its favor on the order of 75% new to 25% renovation. Whereas, a 50/50 split is normal. As monies become tight, Civil Engineering's focus switches to the least expensive projects -- in particular, renovations.

Five of the six individuals were from the mechanical engineering discipline while only one individual was an architect. Therefore, by the nature of their discipline, the mechanicals were more familiar with active solar systems. But, fortunately for the Air Force, these individuals are responsible and aggressive, and therefore, have sought outside educational sources for knowledge on passive solar systems. Four of the five mechanicals attended seminars and conferences held by various solar energy groups. Although knowledge of passive solar systems was at a competent level, only two of the six individuals had prior experience in justifying the use of passive solar systems. Also, these two individuals were actively exchanging ideas with Air Staff in an attempt to institutionalize the use of passive solar systems. The other commands appeared poised for definitive guidance in the area of passive solar energy; but, due to other constraints -- for example, time and command emphasis items -- these individuals are not involved in exploring any new frontiers.

The remainder of the questions were aimed at giving some indication as to the supplemental assessment and guidance the MAJCOMs provide to their bases. In general, the MAJCOMs had no way of recommending specific passive solar techniques on a per project basis and relied on "horse sense" when reviewing a project booklet in determining what techniques are "best" suited for a facility's location and function. In reviewing the PBs, the MAJCOMs found the passive solar energy requirements specified either in the architectural, mechanical, or the designated energy tab. Some of the PBs had the requirement for solar consideration introduced up front in

the section defining the scope of the project. The only numbers provided in the project booklet were the feasibility assessment figures the MAJCOMs had sent the bases. Therefore, the bases transcribe the ETL 84-1 guidance into the PB without any further consideration. The development of design and economic parameters never took place before issuing the PB, and therefore, the Air Force was relying on the A-E to "take the ball and run" with respect to passive solar design. In order to emphasize an energy efficient facility, these parameters provide target figures to the A-E and convey the importance placed on passive solar design by the Air Force

Base-Level Results. The observations made in the Major Command interview were reiterated and magnified at the base-level. That is, the base-level designer's involvement in new or renovation is a direct reflection of MAJCOM's funding level available. Also, the individuals responsible for the inclusion of passive solar concepts were mostly from the mechanical engineering discipline -- in particular, 11 out of the 12 contacted. Therefore, the same problem of familiarity is present except in a magnified manner. In that, the individuals' experience base was limited both by the individuals' responsibility level and years on the job. The problem is exemplified in the prevalent comment made by the interviewed individuals that any passive solar techniques included in the design would have to be introduced by the design A-E. Also, the only PB reference made with respect to the use of passive solar techniques was the SIR calculations made by the MAJCOM. At the present time, even this Air Staff guidance is not conformed with in all instances. This problem

is attributed to both the newness of the guidance (ETL 84-1) and the lack of strong passive solar advocates at all the command levels.

The unfamiliarity with the content and purpose of ETL 84-1 made the interview difficult. In that, none of the bases understood fully why the SIR calculations were sent for the inclusion in the PB and were unaware that the base was identified as a feasible location for the use of unique passive solar. The passive solar techniques prevalent in conversation were the use of southern building orientation and increased insulation levels. These techniques are consider by the Air Force as normal passive solar techniques and do not require economical justification. Therefore, due to this unfamiliarity, the base-level designer is not comfortable with unique passive solar assessment procedures and waits for guidance either from the review process of the proposed MCPs or recommendations from the A-E during the design presentation. As discussed earilier, in both instances the time frame is late and the full benefit of an energy conscious design is not fully realized.

Guidance must be given to the level responsible for initiating the thought process in regards to an energy conscious design and in this case is represented by the base-level design manager. If these tools are unavailable, then the Air Force does not get a product consistent with current Air Force policy.

Sample Calculation

In this section, an example is presented that illustrates the application of the preliminary design guidelines, design-analysis, and

economic evaluation procedures presented in Chapter III. In order to demonstrate this entire process, a step by step method of illustration and explanation is employed. Part of the method makes use of design and analysis worksheets that were adopted from the Passive Solar Design Manual for Naval Installations.

Description of the Facility. The example application is a new Civil Engineering (CE) facility proposed for Lowry AFB, CO. The facility will be used primarily for general office and engineering activities. The orthogonal projection and orientation of the building is shown in Figure 4.1.

The two story structure is approximately 170 feet long, 33 feet deep, and 9 feet high ceilings. Thus, the heated floor space of each floor is 5,610 square feet and the total floor space (Af) is 11,220

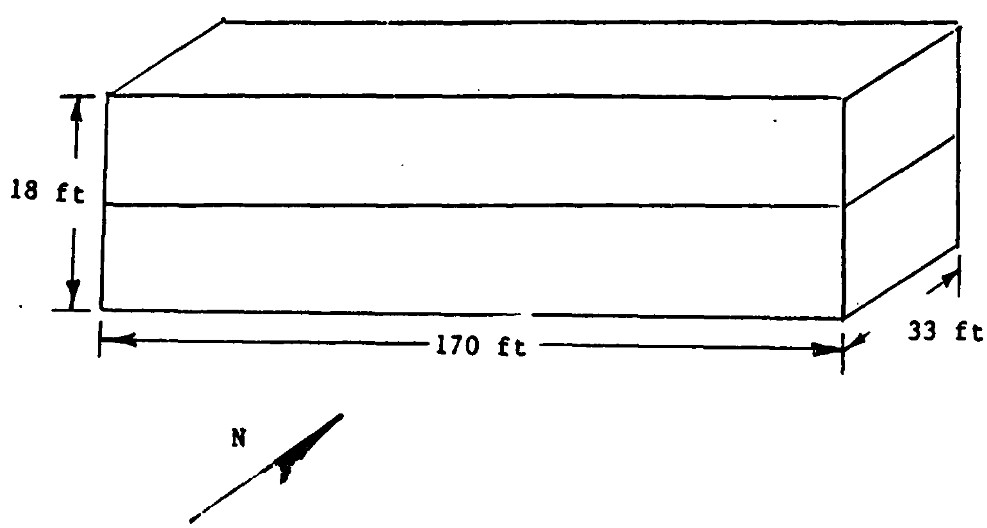


Figure 4.1. Orthogonal projection of the CE facility.

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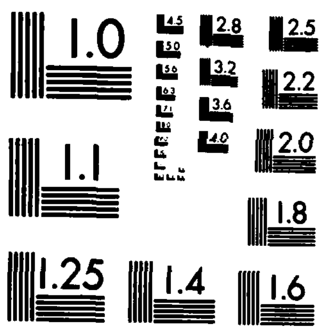
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

square feet. In addition, split ribbed concrete blocks have been specified for the exterior wall construction. The building is oriented with its long dimension along the east-west axis for maximum southern exposure.

Worksheet No 1: Schematic Design Parameters. Worksheet No. 1 outlines and records the results of the preliminary design process. In particular, rough estimates about the building dimensions were used to determine insulation values and to size the solar glazing area.

Step 1. The building size parameters were extracted from Figure 4.1 and calculated with the formulas given on the worksheet. Pf represents the total external perimeter of entire heated floor space (Af) included in the analysis.

Building Size

Heated floor space:	Af = 11,220	sf
Ceiling height:	h = 9	ft
Total external perimeter: (Include external perimeter of each floor)	Pt = 812	ft
External surface area: (Ae = 2 * Af + h * Pt)	Ae = 29,748	sf
External surface-area-to-floor-area ratio:	Ae/Af = 2.65	

Step 2. In step 2, insulation levels are selected. An initial R-value for wall insulation (Rwallo) was obtained from the recommended insulation levels tabulated for each Air Force installation in the Continental United States in Appendix E. The exact Rwallo chosen represents the integer value just below the mid point of the interval.

All R-values in this section were rounded off to the nearest integer value.

Insulation Levels (units = sf $^{\circ}$ F h/BTU)

Rwall = 22
(Rwall is obtained from the contour map in Figure 3.4.)

Rwall = 1/3 * (Ae/Af) * Rwall = 19

Rroof = 1.5 * Rwall = 29

Rperim
or = .75 * Rwall = 14
Rbase

Step 3. This step selects a solar glazing size using a aperature-size ratio. A conservative approach in choosing an initial aperature-size ratio (expressed in percent of floor space) was used for two reasons. First, a smaller solar system increases the opportunity to show economic feasibility of passive solar design by decreasing initial cost of the solar system. Second, smaller systems tend to deviate less from normal Air Force construction practices. As the result of this approach, the minimum value of aperature-size ratio was selected from Appendix E.

Solar Aperature Size

(Ac/Af)o = .18
(The above ratio is obtained from the contour map in Figure 3.4)

Ac = 1/3 * Af * (Ac/Af)o * (Ae/Af) = 1780 sf

Worksheet No. 2: Estimation of Building Load Coefficient (BLC). In order to calculate the BLC, the specified and calculated

design parameters are recorded on Worksheet No. 2. The process used to complete the BLC calculation is outlined in the next three steps.

Step 4. In step 4, the design parameters are specified. The ground floor perimeter (Pg) and area (Ag), roof area (Ar), and south wall area (As) were obtained from the building dimensions in Figure 4.1. Guidelines for the non south window fractions were discussed in Chapter III. The infiltration rate was set at 0.6 air changes per hour. Finally, by using an estimated altitude of 5300 feet, the air density for Lowry AFB was read from Figure 3.5.

Specified Design Parameters

Ground floor perimeter:	Pg =	209	ft
Ground floor area:	Ag =	5610	sf
Roof area: (horizontal projection)	Ar =	5610	sf
South wall area: (includes windows and solar aperature)	As =	3060	sf
Nonsouth window fraction:	NSF =	0.07	
Number of glazings in nonsouth windows:	NGL =	2	
Air changes per hour:	ACH =	0.06	
Air density ratio:	ADR =	0.82	

Step 5. The nonsouth wall area and total wall area were calculated using the given equations.

Calculated Design Parameters

Nonsouth window area: (An = [Pt * h - As] * NSF)	An =	297	sf

Wall area: Aw = 5231 sf
(Aw = Pt * h - Ac - An and is the
total area of all external walls
excluding windows and solar aperatures.)

Step 6. In step 6, calculate the BLC using the appropriate R-values and building parameters. For this example, a slab on grade concrete floor was assumed for floor construction.

Building Load Coefficient (units = BTU/DD)

Walls: (Lw = 24 * Aw/Rwall)	Lw = 6608
Nonsouth windows: (Ln = 26 * An/NGL)	Ln = 3861
Perimeter (slab on grade): (Lp = 100 * Pg/[Rperim + 5]) or	Lp = 2137
Basement (heated): (Lb = 256 * Pg/[Rbase + 8]) or	Lb = ______
Floor (over vented crawl space: (Lf = 24 * Ag/Rfloor)	Lf = ______
Roof: (Lr = 24 * Ar/Rroof)	Lr = 4643
Infiltration:	Li = 21,463
Total:	BLC = 38,705

Worksheet No. 3 System Parameters. Worksheet No. 3 records the system parameters of the reference passive solar system chosen for analysis. The worksheet also provides the capability to analyze mixed systems.

Step 7. Before starting step 7, determine what type of passive system to analyze, then record the system parameters from Appendix F. Generally, experience indicates which passive systems are more

suitable for a given area. But in situations where prior knowledge is not available, then the suggestions provided in the Passive Solar System Selection Section in Chapter III may prove helpful. But, these suggestions are not intended to eliminate the need to consider other unique or special requirements that may influence the selection process.

In this example, a direct gain system was chosen after examining both climatic and facility related factors. The climate data identified Lowry AFB as being in the harsh climate region and also experiences high availability of solar energy. In addition, the problem description stated the facility will be used primarily for general office activities. From this, it was assumed that it would be occupied much more during the day than at night. Thus, a direct gain system was chosen because it provides quick warm-up in the morning, daylighting and southerly view (for aesthetics and employee morale) and is easily controlled by movable insulation.

The design variables were selected from the guidelines provided in Table 3.3. For direct gain systems, these guidelines recommend a mass-area-to-glazing-area ratio of six, four inch thick thermal storage, R9 value for night insulation and double glazing. From this combination of variables, a system number of 6492 is obtained.

First System

System type:	Direct Gain
System number:	6492
Scale factor:	F1 = 0.964

Effective aperature conductance: $G1$ = 2.40
(BTU/^{o} F day sf)

System-state aperature
conductance: Ucl = 0.20
(BTU/^{o} F h sf)

System solar absorptance: α = 0.97

Collection aperature area: Acl = 1780 sf

For mixed systems, repeat the above procedure for determining the system number for the second system. Record the system parameters, then calculate the mixed-system using the weighting procedure given on the worksheet in Appendix J.

Worksheet No. 4 Weather Parameters Weather parameters for the specific location are entered on Worksheet No. 4. Weather data is provided in Appendix G.

Step 8. In step 8, record location and system data. Thermostat setpoint is set by DOD regulation at 68^{o} F. The internal-heat-generation rate Qint, was estimated as the product of daily internal heat generated per person (typically 20,000 BTU) and the probable average number of occupants at the facility (assumed to be 30 persons). The base temperature can now be calculated using the indicated formula. The remaining entries are transposed from Worksheet No. 3. (single system, double glazing).

Location and System Data

State: Colorado

City: Denver

Thermostat setpoint: Tset = 65
(^{o} F)

Internal heat generation rate: Qint = 600,000
(BTU/day)

Base temperature: Tb = 60
(°F)
(Tb = Tset - Qint/(BLC + 24 * Uc * Ac))

Number of glazings on first
solar aperature: NGL1 = 2

Number of glazings on second
solar aperature: NGL2 = ______

Area-weighted system glazing
number: NGL = 2
(NGL = F1 * NGL1 + F2 * NGL2)

Step 9. In step 9, record (VT/DD)o, a_o, and annual heating degree days, (DDy) from Appendix G. In this example, weather parameters corresponding to a base temperature of 60 °F(TR60) were annotated.

Weather Parameters for Due South Orientation

Transmitted-radiation-to-degree-day
ratio: (VT/DD)o = 35.12
(Btu/sf DD)

City parameter: a_o = 0.437

Annual Heating Degree Days: DDy = 5223

Worksheet No. 5: Estimation of Conventional Building Load Coefficient. Worksheet No. 5 provides an estimate for heat loss of the CE building constructed without a solar system and in accordance with present Air Force standards for insulation levels. The two step procedure consists of recording the U-values of building insulation and then calculating the building load coefficient.

Step 10. Using the annual heating degree days from Worksheet No. 4, the U-values for gross walls (Uo), roof (Ur), and floor (Up) are recorded from columns 1, 4, and 8 respectively, from Table I of Appendix D.

Since a slab on grade concrete floor is employed in the CE building, it is necessary to determine the R-value of perimeter insulation by taking the reciprocal of Up.

<u>Maximum Transmission Levels</u> (BTU/sf ^{o} F h)

Walls:	Uo =	0.13
Roof:	Ur =	0.03
Floor: (over vented crawl space)	Uf =	
Perimeter: (slab on grade)	Up =	0.14

<u>Perimeter R-value</u> (sf ^{o} F h/BTU)

Rperim = 1/Up	=	7.14

Step 11. Now the heat losses from the gross walls (includes opaque walls, windows and doors), roof, and perimeter are calculated using the formulas provided and the building parameters from Worksheet No. 2. Also, the figure for heat loss by infiltration (Li) is transposed from Workheet No. 2.

By summing these four component heat losses, the building load coefficient (BLCnorm) is determined.

<u>Conventional Building Load Coefficient</u> (BTU/DD)

Gross walls: (Lw = 24 * Pt * h * Uo)	Lw =	22,800
Roof: (Lr = 24 * Ar * Ur)	Lr =	4039

Floor: Lf = ______
(Lf = 24 * Ag * Uf)
or
Perimeter: Lp = 3344
(Lp = 100 * Pg/(Rperim + 5)

Infiltration: Li = 21,705

Total: BLCnorm = 51,646

Worksheet no. 6: Estimation of Yearly Energy Savings. The annual solar savings of the building is calculated using Workheet No. 6. This figure represents the amount of free energy derived from the passive solar system during the heating season. The five step process is outlined below.

Step 12. First, using parameters previously recorded on Worksheets No.'s 2-4, the scaled solar load ratio (SLR*) is computed.

The Scaled Solar Load Ratio

$$SLR^* = \frac{F * (VT/DD) * \alpha}{BLC/Ac + G} = 1.35$$

Step 13. Next, the yearly heat-to-load ratio is read from the nomogram in Figure 2.12 by using SLR* and city parameter "a" from Worksheet No. 4. This value is 0.17.

The Yearly Heat-to-Load Ratio

(Qaux/Qload) = 0.17

Step 14. By solving the equation provided, the annual auxiliary heating requirement for the passive solar CE facility (Qaux) is calculated as 38 MBTUs. By dividing this figure by the annual heating degree days of 5223 and the floor space of 11,220 sf yields an

auxiliary heating factor of 0.65 BTU/sf DD.

Yearly Auxiliary Heat Requirement (MBTU)

Qaux = 38.2
(Qaux = (Qaux/Qload) * (BLC + G * Ac) * DDy)

Step 15. The annual heating reguirement of the CE facility without a passive solar system and constructed in accordance with ETL 83-9 insulation levels is computed with the next formula. This figure (Qnorm) is 270 MBTUs. Similarly the normal heating factor is 4.61 BTU/sf DD.

Yearly Normal Heat Requirement (MBTU)

Qnorm = BLCnorm * DDy = 270

Step 16. Finally, the amount of energy saved per year by the passive solar building is determined by the difference between Qnorm and Qaux. In this example, the annual solar savings (SS) is 232 MBTU's or 3.96 BTU/sf DD.

Yearly Solar Energy Savings (MBTU)

SS = Qnorm - Qaux = 232

Worksheet No. 7: Estimation of Solar Add-On Cost. The incremental cost of the solar system is computed on Worksheet No. 7. This worksheet is designed to use the construction cost data for reference solar and conventional systems provided in Appendix I. However, if the design of the building being analyzed differs from these reference systems or more accurate cost data is available, then equations 38-41 can be used to estimate unit costs.

Step 17. The exterior wall construction was obtained from the original design specification as split ribbed concrete block. In situations where the exterior wall construction is unknown, a split ribbed block wall should be chosen since it represents the intermediately priced wall system.

Once again using Denver Colorado as the reference city, the city cost index was recorded from Appendix H.

<u>Building and Location Data</u>

Exterior wall construction:		block
City Cost Index:	CCI =	1.016

Step 18. In this step, the differential cost for the direct gain system is determined. First, the system type and number are retrieved from Worksheet No. 3. Next, the thermal wall fraction (TWF) was set at 0.75 (in order to optimize the performance of the thermal storage system.) Lower values of TWF would result in a lower solar add-on costs. Once the system's TWF and exterior wall systems have been chosen, the solar (Csol) and conventional (Cnorm) unit costs are recorded from the tables in Appendix I. The final formula computes the system differential cost (SDC1) as $36,009.

<u>First System</u> (cost = $/sf)

System Type:		Direct Gain
System Number:		6492
Thermal wall fraction:	TWF =	0.75
Solar system unit cost:	Csol =	45.88
Normal construction unit cost	Cnorm =	25.65

System Differential Cost: SDC1 = 36,009

For mixed systems, the above procedure is repeated for the second system using the proper system parameters and collection area (Ac). The mixed system differential cost is then the sum of the two component system differential costs.

Step 19. In the final step, the CCI of 1.016 is used to scale the SDC and yielded a solar add-on cost of $36,585. Dividing this figure by the floor space achieves the solar add-on cost per square foot of floor space of $3.26/sf. It should be noted that the solar add-on cost in this example exceeds the current Air Force funding limitation for unique passive solar application of $2.00/sf.

Solar Add-on Cost (units = $)

SAC = SDC * CCI = 36,585

Worksheet No. 8: Estimation of Savings to Investment Ratio. Worksheet No. 8 organizes the estimation of the savings to investment ratio (SIR) and is the final part in the economic analysis phase.

Step 20. This step consists of recording the pertinent data for the fuel used to heat the building. Heating fuel type is generally given for a particular building. But in order to evaluate the effect of different fuels on the SIR, it is assumed that no fuel type has been specified and that electricity, natural gas, and distillate oil are equally assessible. Fuel efficiencies ranges are listed in the 1977 ASHRAE Handbook of Fundamentals. The mean of these ranges were recorded. Finally, the uniform present worth factor (UPWF) were extracted Table 3 of Appendix A.

recorded. Finally, the uniform present worth factor (UPWF) were extracted Table 3 of Appendix A.

Energy Data

Fuel type:		Electricity
Fuel cost: ($/MBTU)	Fc =	13.77
Fuel efficiency	eff =	0.95
Uniform Present Worth Factor	UPWF =	10.38

Step 21. Using the formula given on the worksheet, the SIR is calculated for each fuel type.

Savings to Investment Ratio

$$SIR = \frac{SS * Fc * UPWF}{0.9 * SAC * eff}$$

Electricity	= 1.06
Natural Gas	= 0.84
Distillate Oil	= 2.03

This chapter has presented an analysis of where the Air Force stands in regard to the institutionalization of passive solar techniques into Air Force facilities and an example as how to generate design and economic parameters for passive solar systems. The next chapter's focus is first to make a few concluding remarks on the current Air Force status in implementing passive solar design, second to forward some recommendations so as to ensure compliance with Air Force directives, and finally, to offer further recommendations for follow-on research in the area of passive solar design.

V. Conclusions and Recommendations

Conclusions

Several conclusions can be made from the previous analysis. First, the Major Commands, in accordance with ETL 84-1, are accomplishing the preliminary assessment calculations in order to determine a location's potential for the use of passeve solar systems. If this assessment is favorable (i.e. the SIR is greater than one), then the calculations are passed to the base for inclusion in the project booklet (PB) for proposed MCPs. Since this action fulfills the requirements set forth in ETL 84-1, the MAJCOM requires the base to do no further feasibility assessments of passive solar systems. Therefore, the base design manager relies on the design A-E to recommend passive solar techniques and incorporate these techniques into the facility's design, even though the A-E is given minimal encouragement in the form of directed guidance from the PB. If the A-E is not familiar with passive solar techniques or, in general, is not an advocate of solar energy, then the passive solar requirement specified in the PB may not be given adequate consideration.

Second, presently the base-level design manager is not given supplemental guidance to assist in complying fully with ETL 84-1. In particular, the design manager has no method for determining feasibility of specific passive solar techniques on a per project basis, and therefore, is unable to make recommendations in the PB. The design manager must have the capability to specify design and

economic parameters for passive solar systems in order to set figures for the A-E to either confirm or refute.

Third, even though most of the individuals contacted at base-level were familiar with passive solar techniques, the prevalent techniques mentioned in conversation were the maximization of southern exposure and the increasing of insulation levels. Since the Air Force considers these normal passive solar techniques, an economic feasibility assessment is not required. These conversations highlighted the confussion and lack of understanding as to the basic principals underlying the purpose for the required assessment in ETL 84-1. In that, the individuals were not comfortable in addressing unique passive solar systems (eg. trombe walls and direct gain) and were not aware of the availability of extra project money so as to incorporate a unique passive solar system into the design if proven economically feasible. The problems arise due to the lack of complete guidance that specifies the base-level's responsibilities and provides a means to fulfill these responsibilities in an accurate and timely manner.

Fourth, since most of the individuals responsible for ensuring the inclusion of passive solar techniques in the PB were mechanical engineers, definitive guidance in this area is critical. In that, the mechanical engineer is more familiar with active systems than passive systems by the nature of mechanical discipline. Therefore, an educational process on unique passive solar techniques must take place hand in hand with definitive guidance. These steps will encourage the flow of creative ideas with respect to the use of

passive solar techniques while at the same time enhancing Air Force directives.

Fifth, in regard to the sample calculations, the feasibility of unigue passive solar heating is dependent upon many interacting variables. This dependent interaction lends the variables to a sensitivity analysis in order to illustrate the following important points.

1. By choosing not to use the wall for thermal storage (i.e. TWF = 0), the SIR for natural gas would increase from 0.83 to 1.37 and decrease the solar add-on cost by $14,088. This strategy implies that the thermal storage becomes solely a responsibility of the floor mass. Since the system cost is reduced and the SIR is increased, this stategy makes the passive solar system more attractive,. However, the efficiency of the thermal storage medium is reduced. In that, vertical surfaces (walls) distributes the heat about the direct gain zone more uniformly (Vol III, 1982).

2. Although the cost per square foot of the sample calculation exceeded the current Air Force limit of $2.00/sf, the system still gave an SIR of greater than one in all cases except natural gas.

3. In comparing the SIRs of both direct gain and unvented trombe wall systems, the direct gain system showed more return for investment (i.e. a larger SIR), thereby validating the methodolgy used in initial system selection. That is, since certain systems are better suited for different climate types, the methodology does make this discrimination in system types.

4. If the base temperature (Tb) is decreased due to internal heat

gains from the current Air Force assumption of 65° F, then several variables are affected. First, the DD figure is decreased. Second, since the DD figure represents a datum by which the heating requirement is measured, then the heating load is decreased for the facility. This reduction allows less opportunity for solar savings due to passive solar systems. Therefore, this report's methodology provides the designer with the tools to account for not only the facility's location but also the facility's function. Failure to consider the function of the facility could result in overheating.

5. The use of the low guidelines for the collector-to-floor ratio $(Ac/Af)o$ proved more cost effective than the high value. In that, the incremental cost of the larger solar system did not result in a proportionate increase in solar savings.

Recommendations

In order to complete the institutionalization of passive solar systems in design of Air Force facilities, detailed PB guidance must be generated at either MAJCOM or Air Staff level to direct: 1) what type of design and economic parameters should be included in the PB; 2) the methodology for detemining the values for these parameters; and 3) where and how the parameters should be stated in the PB.

Several design and economic parameters are needed to accurately define a passive solar system and validate its economic feasibility. These parameters are: 1) recommended insulation levels; 2) solar glazing size; 3) energy savings; and 4) savings-to-investment ratio.

The methodology to develop these parameters should be simple and straightfoward. One methodology was described in chapter III and is presented in worksheet format in Appendix J. In order to maximize use, these worksheets should be incorporated in a computer program on the Work Information Management System (WIMS) being acquired by the Air Force for Civil Engineering Organizations. The WIMS program will allow easy repetition of the parameter calculations in order to evaluate a variety of passive solar systems.

The presentation and location of these parameters should be standardized in the PB to facilate interpretation and verification. In order to emphasize the energy concerns of the Air Force, a separate tab should be formated and included in the PB. An example is presented in Appendix K. This example of an Energy Tab shows how to include the parameters as line items in the PB. Attachments will be needed to support the calculations of these parameters. The attachments should be the print-outs generated by the WIMS computer program.

Finally, the PB should stipulate to the A-E that a requirement exist for at least two preliminary sketches of the facility under design be presesented to the base-level organization at the 15% design phase for review and screening. This action will ensure that in the early stages of design when energy consiousness is imperative that passive solar techniques are given proper consideration.

Appendix A: ETL 84-1

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D C
20332

10 JAN [illegible]

REPLY TO ATTN OF: LEEEU

SUBJECT: Engineering Technical Letter (ETL) 84-1: Solar Applications

TO: ALMAJCOM/DEE	AFIT/DET/DEM	AFRCE/CR	AFRCE/ER	AFRCE/BMS
HQ USAFE/DER	HQ AFCC/DEO	AFRCE/WR	AFRCE/SAC	

1. Purpose: This letter

a. Supersedes ETL 82-5, dated 10 Nov 82.

b. Implements the Military Construction Codification Act, of 10 USC 2801, Para 2857.

(1) Requires design of all new facilities to include consideration of solar energy systems where they have the potential for significant savings of fossil-fuel-derived energy.

(2) Requires consideration be given to heating and/or cooling active and passive solar systems.

(3) Authorizes additional scope and cost per square foot of the project for the solar application(s) above any other limitation.

(4) Requires contracts for construction to include solar system installation when proven cost effective during the design process.

c. Establishes a procedure for preliminary solar assessments that must be followed by the Base or MAJCOM.

d. Establishes criteria that must be followed and data that must be furnished by the designer.

e. Establishes a requirement to input data into the new Program, Design, and Construction (PDC) system. Note: If the PDC system is not in operation to input this data, continue to input data into the DEACONS system.

f. Is effective as follows:

(1) For projects FY 86 and earlier which have not reached the 30% design stage as of the date of this letter.

(2) For projects being developed: Starting with the FY 87 MCP program.

g. Is not mandatory to install active solar systems in remote or overseas locations where local maintenance capability does not exist.

2. Implementation

a. Active Solar.

(1) Description. This type of system generally consists of roof or ground mounted solar collectors, a piping system, a liquid or air heat transfer medium, pumps, heat exchanger and thermal storage tank or mass.

(2) Solar Scope and PA. In order to include active solar heating and/or cooling systems in a Military Construction Project an increase in scope and PA can be authorized above any other limitation with respect to the number of square feet or cost per square foot of the project.

(3) Responsibilities.

a.) MAJCOM

1. A solar feasibility assessment will be performed per attachment 1 early each calendar year for the next MCP Command Submittal. In other words, assessments done in Jan 84, will be used to determine which projects in the FY 87 MCP Command Submittal must be analyzed further by the designer.

2. The Command Submittal should contain an additional line item under Supporting Utilities entitled "Active Solar Application." This solar PA will not exceed 25% of the cost of the mechanical system.

3. The requirement for further active solar analysis will be included in the Project Booklet (PB) with the results (SIR) from the feasibility assessment. This action will validate the requirement for further analysis by the A-E.

4. If active solar applications are not cost effective, the PB will include the statement: "Active Solar is not cost effective." The A-E will not perform additional solar analyses.

5. Solar assessments for each base will be input into PDC input screen SOLRUPDC (Atch 2). The Control File for this screen is BSOL (Atch 3). If the PDC system is not in operation, the MAJCOM will provide this information to LEEEU and HQ AFESC/DEB. The bases should be made aware of these assessments to enable them to also screen their PBs for incorporation of active solar applications.

b.) Design Manager.

1. Active solar analyses will be performed by the designer per attachment 4. The PB must indicate the solar assessment Savings to Investment Ratio (SIR) to be greater than 1.0 for the particular fuel(s) to be used at the proposed building.

2. The solar application will be designed as an additive with its approved solar PA.

3. The 35% design results of the designer's solar analysis will be reported in PDC input screen SOLAUPDC (Atch 5). The Control File for this screen is SOLD (Atch 6). If PDC is not in operation, this information will be provided in the DEACONS.

4. If active solar is cost effective at the 35% design stage, the system will be designed to the 100% design stage. The solar PA will be adjusted to support the cost of the optimum size solar system at the 35% design stage.

5. The solar PA will not be used to support any non-solar part of the project unless the solar application proves to be not cost effective.

6. At the time of contract award, the solar CWE will be updated to reflect the true cost of the solar application. If still cost effective, the solar application will be awarded as part of the basic project.

7. If solar is not cost effective, the information of Para (2) will be provided in the PDC with a statement in the "COMMENTS" "SOLAR IS NOT COST EFFECTIVE".

b. Passive Solar.

(1) Reference ETLs: Normal Passive Solar Applications and Unique Passive Solar Applications. This section pertains to unique passive solar applications only. Any application which is intended to provide solar heating, solar cooling, or daylighting (glazing more than 15% of area served) through passive means is to be considered a unique passive solar applications. These type applications require additional analysis, structure and funds, and must be proven cost effective IAW Congressional guidelines. It is anticipated that unique passive solar application will reduce the building energy consumption from 40 to 70 percent below the DOD required energy budget figures. Reference ETL: Energy Budget Figures.

(2) Solar Scope and PA. In order to include in a military construction project passive solar heating, cooling, or both heating and cooling, and/or a daylighting system, an increase may be authorized over any other limitation with respect to the number of square feet or the cost per square foot of the project.

(3) Responsibilities.

a.) MAJCOM

1. A feasibility assessment will be performed early each calendar year for the next MCP Command Submittal (Reference Attachment 7). In other words, assessments done in Jan 84, will be used to determine which projects in the FY 87 MCP Command Submittal must be analyzed further by the designer.

2. For those bases with an SIR greater than 1.0, the MAJCOM will determine which projects should include daylighting and/or passive solar heating and cooling requirements. Based on historical data, some buildings which lend themselves well to unique passive solar applications are: admin, maintenance, child care centers, recreation centers, gymnasiums, post offices, and other facilities.

3. The Command Submittal DD Form 1391s should include a separate line item under Supporting Facilities entitled "Passive Solar Applications." This cost will be based on the anticipated solar scope but will not exceed two dollars per square foot of total building scope.

4. The passive solar requirement is to be included also in the Project Booklet(PB) in the Architectural Section. The assessment SIR value must also be included to validate the requirement.

5. The solar assessment for each base will be input into PDC input screen SOLRUPDC (Atch 2). The Control File for this screen is BSOL (Atch 3). If the PDC system is not in operation, the MAJCOM will provide this information to LEEEU and HQ AFESC/DEB. The bases should be made aware of these assessments to enable them to also screen their projects for incorporation of unique passive solar applications.

b.) Design Manager.

1. Passive solar analyse ll be performed by the designer per attachment 8. It will be gned as an additive with its approved solar PA.

2. The results of the des er's solar analysis will be reported in PDC input screen SOLPUPDC (Atch 9). The Control File for this\screen is SOLD (Atch 6). If PDC is not in operation, this information will be provided in the DEACONS.

3. If the passive solar application(s) is cost effective at the 35% design stage, it will remain as part of the basic project. The solar PA will not be used to support any non-solar part of the project unless the solar application proves to be not cost effective.

4. The solar CWE will be updated at contract award to reflect the true cost of the solar application. If cost effective, it will be awarded as part of the basic project.

5. If solar is not cost effective, the design data of input screen SOLPUPDC will be provided with the statement "SOLAR IS NOT COST EFFECTIVE" in the "COMMENTS" field, in addition to the other solar data.

6. The designer should provide at least three concept sketches at an on-board review. The concept selected by the Base or MAJCOM should be based not only on aesthetics, but also on energy efficiency.

7. A copy of the proposed concepts will be provided to LEEEU for information.

8. A copy of the 35% submittal energy analysis with elevation and floor plan layouts will be provided to LEEEU for information. This analysis must indicate the final energy budget figure.

FOR THE CHIEF OF STAFF

Refugio S. Fernandez

Refugio S. Fernandez
Acting, Chief, Utl Branch
Engineering Division
Directorate of Eng & Svcs

9 Atch
1. MAJCOM ACTIVE SOLAR ASSESS
2. SOLAR F[illegible]IBIL INPUT SCREEN
3. BSOL CONTROL FILE

4. ACT SOLAR DESIGN CRITERIA
5. ACT SOL INPUT SCREEN
6. SOLD CONTROL FILE
7. MAJCOM PASSIVE SOL ASSESS
8. UNIQUE PASS DESIGN CRITERIA
9. PASSIVE SOLAR INPUT SCREEN

cc: AAFES/E
ANG/DEE
DAEN-ECE-S
NAVFAC/CODE-052
OASD (MRA & L) LM
AFMPC/MPCXC
HQ AFESC/CA

Active Solar Feasibility Assessments

1. Introduction. This is a quick, simple assessment procedure for active solar applications to be used only during the project development stage. It combines Congressional life-cycle costing criteria with state-of-the-art solar system performance to indicate the relative potential of active solar at each base, according to fuel type and cost.

2. General. The MAJCOM will calculate for each base and for each of its fuels, the savings to investment ratio (SIR) according to the following basic equation:

$$SIR = [(0.50XA/FXE_f)(C_f)(UPWF) - 0.01/(S)(BCF)]/0.90S.$$

a. Assumptions:

(1) 50% solar fraction.

(2) 1% of total investment for O & M expenses.

(3) 10% investment tax credit

b. Nomenclature

(1) SIR = Savings to investment ratio (must be equal to or greater than 1.0 for consideration and design.)

(2) A = Available annual insolation/SF of collector (MBTU/SF).

(3) F = Energy saved equivalent factor (BTU).

(4) E_f = Heating plant system efficiency

(5) C_f = Cost per unit of fuel saved ($1 MBTU).

(6) UPWF = Uniform present worth factor for fuel type.

(7) BCF = Benefit cost factor for O & M.

(8) S = System unit cost per SF of collector.

3. Procedure.

a. The MAJCOM is to complete the attached Table 1 and Table 2 for each of their bases and fuels. Until further notice, the equation in Table 2 will be used.

b. The information of Table 1 and Table 2 will be input into the PDC input screen SOLR (Atch 2). The PDC solar control file is BSOL (Atch 3). If the PDC system is not in operation, copies of Tables 1 and 2 wil be sent to LEEEU and HQ AFESC/DEB. The bases should be made aware of these results.

c. If the SIR is one or greater for a particular fuel(s) and base then the Base or MAJCOM must screen all proposed facilities using that fuel(s) from that base to determine which projects will require comprehensive active solar analyses during the design process. The Base or MAJCOM will include the requirement for the solar analysis in the project booklet (PB). The SIR value(s) from the solar assessment will also be included to validate the requirement on the PB.

d. If the SIR is less than one, then a statement on the project booklet, Tab E, should read: "Active Solar is not cost effective."

TABLE 1

BASE FUEL COST DATA

MAJCOM: ______________________________

BASE	FUEL OIL 1/	$ per MBTU2/ ELECTRICITY	NAT	GAS/LPG	OTHER

1/ Denote fuel oil grade; i.e., No. 1, No. 4, etc.
2/ Annual average dollars at the site including conversion and distribution losses. For electricity, use 3413 BtuH per KWH as SIR equation assumes site energy savings.

ACTIVE SOLAR FEASIBILITY ASSESSMENT

MAJCOM: ______________________________

Savings to Investment Ratio Equation: 1/

SIR = [((A. C_f.UPWF/2) - 7.5)/0.9S]

A = (MBTU/SF - yr) Use Figure 1 for CONUS, Alaska & Hawaii.

3/ S = System cost per SF of collector. Use $64.00 or cost at the base.

C_f = ($ per MBTU) See Table 1

UPWF= Uniform Present Worth Factor. See Table 3

BASE	SIR2/ FUEL OIL	ELECTRICITY	NAT GAS/LPG	OTHER

1/ Assumptions:

a. 50% solar heating fraction
b. 1% of investment allocated as recurring annual O&M expense
c. 10% investment tax credit
d. 0% differential inflation rate for O&M (UPWF for 25 yrs = 11.65)
e. 7% discount rate
f. 25 year system lifetime
g. System costs equal to $64.00 per collector square footage in FY 83 dollars
h. Regional fuel differential inflation rates extracted from 18 Nov 81 Fed. Register, Vol. 46, No. 222

2/ Calculate the SIR for each primary fuel source on each base using the SIR equation. Must be equal to or greater than 1 to be cost effective.

3/ For overseas locations, complete the worksheet at ATCH 1 sht 10 of 11 using solar radiation data corresponding to your location listed in Table 4 and the tilt correction factor of Table 2. If other long term mean daily solar radiation data are available at your location, insert it into the worksheet, with proper units.

TABLE 3*

UPW Discount Factors Adjusted for Energy Price Escalation

The following 25 year "modified" uniform present worth discount (UPW) factors are based on a 7% discount rate and include the DOE projected escalation rates in enrgy prices developed from the mid-term energy forecasting system (MEFS), for the periods mid 1981 to mid 1985, mid 1985 to mid 1990, and mid 1990 to mid 1995 and beyond. Overseas activities should use values given for the United States average.

TABLE 1-REGION 1:	Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island.
TABLE 2-REGION 2:	New York, New Jersey, Puerto Rico, Virgin Islands.
TABLE 3-REGION 3:	Pennsylvania, Maryland, West Virginia, Virginia, District of Columbia, Delaware.
TABLE 4-REGION 4:	Kentucky, Tennessee, North Carolina, South Carolina, Mississippi, Alabama, Georgia, Florida, Canal Zone.
TABLE 5-REGION 5:	Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio.
TABLE 6-REGION 6:	Texas, New Mexico, Oklahoma, Arkansas, Louisiana.
TABLE 7-REGION 7:	Kansas, Missouri, Iowa, Nebraska.
TABLE 8-REGION 8:	Montana, North Dakota, South Dakota, Wyoming, Utah, Colorado.
TABLE 9-REGION 9:	California, Nevada, Arizona, Hawaii, Trust Territory of the Pacific Islands, American Samoa, Guam.
TABLE 10-REGION 10:	Washington, Oregon, Idaho, Alaska.
TABLE 11-REGION 11:	United States Average.

REGION	1	2	3	4	5	6	7	8	9	10	11
Elec.	11.81	12.94	14.46	15.23	14.33	14.40	13.82	10.38	13.40	16.10	14.19
Distillate Oil	17.79	17.76	17.64	17.68	17.93	17.87	18.00	17.94	18.10	18.10	17.79
Residual Oil	21.74	21.55	21.42	22.19	14.07	22.27	14.12	22.50	22.56	22.60	18.09
Nat. & LP Gas	18.11	18.23	19.55	21.20	18.92	17.45	19.62	16.88	15.93	13.46	17.84
Coal	17.44	20.33	20.71	20.42	19.92	20.53	20.25	18.95	19.40	24.58	20.76

*Extracted from 18 Nov 1981 Federal Register, Vol. 46, No. 222

AVERAGE ANNUAL GLOBAL SOLAR RADIATION ON A SOUTH FACING SURFACE, TILT = LATITUDE

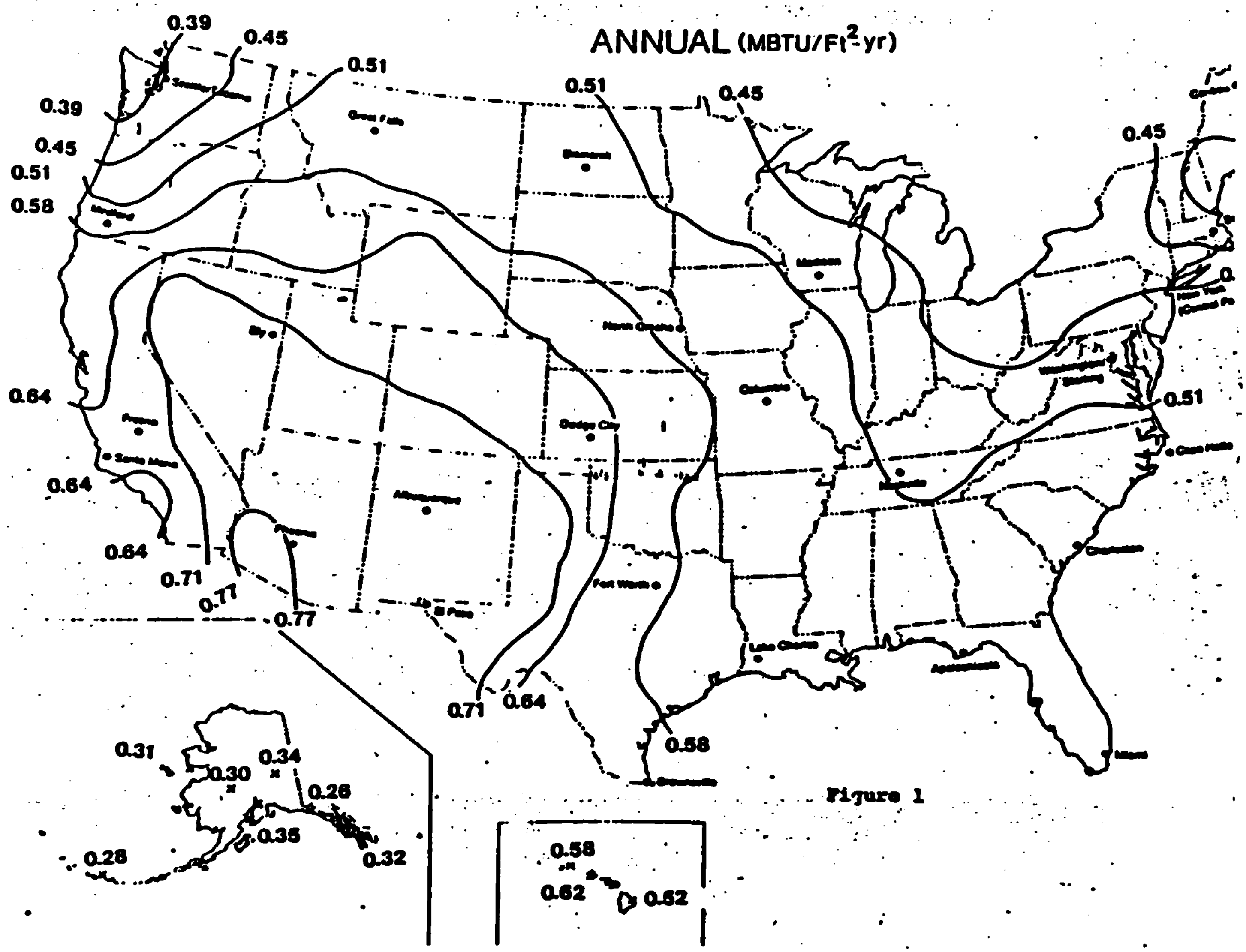

Figure 1

Table 4

SOLAR CLIMATOLOGY

Mean Daily Global Insolation (Langleys) - Overseas

LOCATION	Elev Ft.	Lat	Long	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Code
AZORES		N	W														
Angra	92	38 07	27 02	160	218	294	413	512	576	516	402	396	288	165	152	349	a
Corvo	28	39 40	31 07	160	209	307	421	503	520	545	510	408	270	170	133	346	a
Lajes Fld	180	38 46	27 06	160	218	294	413	512	576	516	402	396	288	105	153	349	1
Ponta Delgado	36	37 45	25 40	190	254	347	431	522	514	552	539	459	341	200	175	378	a
GERMANY		N	E														
Karlsruhe/AAF	427	49 01	8 25	68	148	240	342	502	518	525	370	302	202	69	52	278	a
Konigstein-Taunsus	68	50 11	8 29	68	120	231	347	428	458	444	387	283	167	70	42	264	1
Potsdam	344	52 23	13 04	58	104	212	319	414	471	441	364	274	143	61	40	242	
Ramstein AB/Lanstuhl	780	49 26	7 36	51	103	213	319	423	425	416	368	265	154	74	47	253	2
Rhein-Main AB	368	50 02	8 34	68	120	231	347	428	458	444	387	283	167	70	42	234	3
Saarbrucken		49 13	7 01	51	103	213	319	423	425	416	368	265	151	74	47	238	a
Wurtzburg	836	49 48	9 54	90	134	237	334	398	427	456	339	340	171	56	46	256	a
GREECE		N	E														
Hellinikon Apt/Athens	33	37 54	23 44	180	276	334	457	516	577	572	498	396	276	187	161	369	a
JAPAN																	
Kadena AB/Okinawa	140	26 21	127 46	172	209	258	311	294	389	466	418	379	268	198	166	294	4
Naze/Okinawa		28 23	129 30	172	209	258	311	294	389	466	418	379	268	198	166	294	a
Tokyo	9	35 41	139 46	186	226	268	306	336	297	329	331	249	198	181	166	256	a
Yokota AB	456	35 44	139 20	186	226	268	306	336	297	329	331	249	198	101	166	256	5
PHILLIPINE ISLANDS		N	E														
Clark AB	478	15 11	120 33	308	302	436	518	460	433	352	364	355	364	355	347	383	6
Quezon City		14 40	121 05	308	302	436	518	460	433	352	364	355	364	355	347	383	a

1/ Langley = 3.69 Btu/ft^2-yr

ATCH 1
(8 of 11)

Table 4

SOLAR CLIMATOLOGY

Mean Daily Global Insolation (Langleys) - Overseas

LOCATION	Elev Ft.	Lat	Long	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann	Code
TURKEY		N	E														
Incirlik AB/Adena	239	37 00	35 26	180	276	334	457	516	577	572	498	396	276	187	161	369	7
MARIANA ISLANDS		N	E														
Guam/Agana NAS	298	13 29	144 48	390	460	560	620	590	580	470	480	440	430	400	370	482	8
Guam/Andersen AFB	624	13 35	144 55	390	460	560	620	590	580	470	480	440	430	400	370	482	8
Saipan	696	15 14	145 46	390	460	560	620	590	580	470	480	440	430	400	370	482	a
Spaipan/Kobler Fld	108	15 07	145 43	390	460	560	620	590	580	470	480	440	430	400	370	482	8
Tinian/No. Aux Fld	85	15 04	145 38	390	460	560	620	590	580	470	480	440	430	400	370	482	8
/W. Aux Fld	252	15 00	145 38	390	460	560	620	590	580	470	480	440	430	400	370	482	8
UNITED KINGDOM																	
Kew	-	51 04	-	50	89	182	270	368	418	373	323	245	137	66	40	214	9
WAKE ISLAND																	
Wake Island AFB	14	19 17	160 38	438	518	570	623	644	648	636	623	587	530	465	399	558	a

a. World Distribution of Solar Radiation. Report No. 21, U. of Wisconsin, 1966.

1. Same as Angra
2. Same as Saarbracken
3. Same as Konigstein-Taunus
4. Same as Naze
5. Same as Tokyo
6. Same as Quezon City (Manila)
7. Same as Athens
8. Same as Spaipan
9. Kew solar radiation (1959-1968)

ATCH 1 (9

WORKSHEET

Annual Average Global Solar Radiation

Base: ______________________

Month	(Btu/SF/day) I_n	X	Days in Month	/	(Btu/MBTU) C	=	(MBTU/SF/Mo) I_m	X	(Table 5) R	=	(MBTU/SF/MO) I_r
Jan			31		10^6						
Feb			28		10^6						
Mar			31		10^6						
Apr			30		10^6						
May			31		10^6						
Jun			30		10^6						
Jul			31		10^6						
Aug			31		10^6						
Sep			30		10^6						
Oct			31		10^6						
Nov			30		10^6						
Dec			31		10^6						

Total I_T (MBTU/SF/yr) ______________

ATCH 1 (10 OF 11)

LAT		$H_T/\bar{H}$ 1	2	3	4	5	6	7	8	9	10	11	12
L	24°	1.34	1.20	1.08	0.97	0.89	0.87	0.89	0.96	1.08	1.20	1.33	1.40
	32	1.56	1.33	1.15	0.99	0.88	0.85	0.88	0.98	1.15	1.33	1.55	1.66
	40	1.91	1.53	1.26	1.02	0.89	0.84	0.88	1.01	1.25	1.53	1.89	2.09
	48	2.48	1.83	1.41	1.08	0.90	0.84	0.89	1.05	1.39	1.82	2.43	2.80
	56	3.58	2.32	1.64	1.16	0.92	0.85	0.91	1.12	1.61	2.31	3.47	4.32
	64	6.44	3.22	2.01	1.27	0.95	0.85	0.93	0.61	1.95	3.17	6.22	11
(LAT −10°)	24	1.22	1.14	1.07	1.00	0.96	0.94	0.95	1.00	1.11	1.14	1.22	1.26
	32	1.43	1.27	1.14	1.02	0.95	0.92	0.95	1.02	1.14	1.27	1.42	1.50
	40	1.75	1.46	1.25	1.06	0.96	0.92	0.95	1.05	1.24	1.46	1.74	1.89
	48	2.28	1.74	1.40	1.12	0.97	0.92	0.96	1.10	1.38	1.74	2.24	2.55
	56	3.31	2.22	1.63	1.21	1.00	0.93	0.99	1.18	1.60	2.20	3.22	3.95
	64	5.96	3.08	1.99	1.69	1.03	0.94	1.01	1.28	1.93	3.04	5.78	10
(LAT +10°)	24	1.42	1.22	1.06	0.91	0.81	0.77	0.81	0.90	1.06	1.23	1.41	1.50
	32	1.64	1.36	1.13	0.92	0.80	0.76	0.79	0.91	1.12	1.36	1.63	1.77
	40	2.01	1.56	1.23	0.95	0.80	0.75	0.79	0.94	1.22	1.56	1.99	2.23
	48	2.60	1.87	1.38	1.00	0.81	0.74	0.80	0.98	1.36	1.85	2.55	2.97
	56	3.75	2.42	1.61	1.08	0.83	0.75	0.81	1.04	1.57	2.34	3.63	4.56
	64	6.71	3.26	1.96	1.18	0.85	0.75	0.83	1.13	1.90	3.22	6.48	12

$H_T/\bar{H}$ = Ratio of Total Solar Radiation on a Tilted Surface to the Horizontal

ASHRAE Applications Handbook 1978, Chap 58, Table 3

Atch 1
(11 of 11)

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

 1          ACTIVE AND UNIQUE PASSIVE SOLAR FEASIBILITY ASSESSMENT
 2        ********************************************************
 3                               FY: **
 4                     MAJCOM: ***   BASE: ********
 5                ---------------------------------------
 6               | BASE FUEL COST DATA(PROGRAM YR $ PER MBTU)
 7               ******************************************
 8        FUEL OIL   ELECTRICITY   NAT. GAS    COAL    STEAM   OTHER
 9         *****       *****        *****     *****   *****   *****
10
11               ACTIVE SOLAR SAVINGS TO INVESTMENT RATIO(SIR)
12                    **********************************
13      FUEL OIL   ELECTRICITY   NATURAL GAS    COAL    STEAM   OTHER
14      ****          ****          ****        ****     ****    ****
15
16                         UNIQUE PASSIVE SOLAR SIR
17                        *************************
18                                 ****
19   COMMENTS: *******************************************************
20             *******************************************************
21
22                                       FILE: BSOLR SCREEN: SOLR
23   ROWS 23 AND 24 ARE RESERVED FOR DATA ENTRY MESSAGES.
24

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

ATCH 2

FILE NAME: [illegible]

[illegible] RECORD SIZE IS [illegible]

[illegible] KEY FIELD = SOLBASE

[illegible]	[illegible]
[illegible]	YES
[illegible]	YES
[illegible]	YES

DESCRIPTION: BASE WHERE SOLAR APPLICATION IS BEING CONSIDERED.

FIELD NAME	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	CLEAR AFTER	CATG/TYPE	CUM FIELD	VALIDATION	ALIAS NAME
SOLBASE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				[illegible]
SOLMAJ	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				
SOLCOAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				COAL COST($/MBTU)(10.59)
SOLELECT	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				ELECTRICITY COST($/MBTU)(10.59)
SOLFOL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				FUEL OIL COST ($/MBTU)(10.54)
SOLNAGAS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				NATURAL GAS COST($/MBTU)(10.53)
SOLOTHER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				OTHER FUEL COST($/MBTU)(10.45)
SOLSIRAC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				COAL SIR(10.3)
SOLSIRAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				ELECTRICITY SIR(10.4)
SOLSIRAF	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				FUEL OIL SIR(10.4)
SOLSIRAO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				OTHER FUEL SIR(10.5)
SOLSIRAS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				STEAM SIR (10.6)
SOLSIRAP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				PASSIVE SOLAR SIR(10.7)
SOLSIEAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				STEAM COST($/MBTU)(10.58)
SOLINSOL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				INSOL(AN AVG DAILY LANGLEY:325)
SOLSIRAN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				NATURAL GAS SIR(10.1)
SOLFCOM1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				SOLAR COMMENTS
SOLFCOM2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				SOLAR COMMENTS
SOLFY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	YES				FISCAL YEAR FOR SOLAR APPLICA

ATCH 3

DESIGN CRITERIA

ACTIVE SOLAR ANALYSIS

1. Economic Analysis

a. A solar energy system for a facility shall be considered cost effective if the difference between the original investment cost of the energy system for the facility with a solar energy system and the original investment cost of the energy system for the facility without a solar energy system can be recovered over the expected life of the facility or system, whichever is less.

b. The determination of whether a cost differential can be recovered over the expected life of a facility shall be made using the life cycle cost analysis procedure described by the latest revision of National Bureau of Standards (NBS) Handbook 135, "Life-Cycle Cost Manual for the Federal Energy Management Program." This procedures shall include:

(1) All capital expenses and all operating and maintenance expenses (1% of system cost) associated with the energy system with and without a solar energy system over the expected life of the facility or system, whichever is shorter.

(2) Actual fossil fuel costs at the facility with a rate of growth the latest DOE tables published in the Federal Register. Overseas locations shall use values derived from the tables given for the United States average. Use the industrial rates.

(3) A discount rate of 7 percent per year for all expenses of the energy system.

(4) Note: Do not size the solar system to accommodate standby power.

c. Reduce the original investment cost of the solar energy system by 10 percent to reflect an allowance for an investment cost credit.

2. System Performance Parameters. The size of the solar system shall be optimized based on the highest net life cycle savings to investment ratio (SIR). However, the size must provide not less than 25 percent of the required space heating or cooling nor less than 35 percent of the domestic water heating (year-round basis).

3. Types of systems. The designer will analyze the following systems:

a. Space heating and domestic water heating.

b. Space heating only.

c. Water heating only.

d. Solar cooling systems where the total air conditioning load is greater than 40 tons.

4. Architectural Compatibility. Whether ground mounted or building mounted, systems shall be designed to be architecturally compatible with the total environment. All projects with solar applications will be designed to be architecturally acceptable if active solar is not constructed.

5. Type of Energy Analysis. The active solar system will be evaluated by the designer prior to the 30 percent design stage. The solar analysis shall be "BLAST", "F-Chart" or similar solar analysis and the economic analysis described in Para 2.

6. Weather Data. Site specific average monthly and annual daily solar radiation on a horizontal surface will be used in the required analysis. Reference publication entitled "Insolation Data Manual" No. SERI/SP-755-789, Oct 1980. This data is in Langleys per day. To convert to BTU per SF per day, multiply times 3.69. To convert horizontal radiation to different collector tilts, use Atch 2. Reference report AFCEC-TR-77-12 (or NGSIR-77-1238) "Technical Guidelines for Energy Conservation" of the Air Force Energy Conservation Handbook dated July 1977, for average seasonal makeup water temperatures. Ambient air temperature data can be obtained from AFM 88-29. Engineering Weather Data on the local weather services.

7. Cost Effective. If the solar system is cost effective, the designer will provide the PDC input data per atch 5 at the 30 percent design stage. The design of the system can then proceed to 100%. At 100%, the designer will provide any updated information for the PDC.

8. Not Cost Effective. If the solar system is not cost effective, the designer will provide the PDC input data per atch 5 at the 30 percent design stage. Design of the solar system will then be terminated.

ATCH 5

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........    .......................................   ......................................
....         1         2         3         4         5         6         7         8 ....
.... 12345678901234567890123456789012345678901234567890123456789012345678901234567890 ....
.........................................................................................
.  .                                                                                  .  .
. 1.                             ACTIVE SOLAR DESIGN STATUS                           . 1.
. 2.                   ***************************************                        . 2.
. 3.  PDC  *********** ******* ******************** FY  **  PA  *******               . 3.
. 4. ---------------------------------------------------------------------------     . 4.
. 5.                   SOLAR PA:  *******    SOLAR SCOPE:  ******                     . 5.
. 6.      *************************DESIGN RESULTS**********************               . 6.
. 7.  SOLAR CAE:                                                        ******        . 7.
. 8.  TYPE(S) FUEL DISPLACED:                                           ********      . 8.
. 9.  TYPE SOLAR APPLICATION(S):                                        *******       . 9.
.10.  AGE DESIGN SIR:                                                   ****          .10.
. 1.  SIMPLE PAYBACK:                                                   ****          . 1.
. 2.  DISCOUNTED PAYBACK:                                               ****          . 2.
. 3.  AE ANALYSIS METHOD:                                               **            . 3.
. 4.  SOLAR PERCENT OF BUILDING ENERGY SYSTEM(LIGHTING/COOLING/HEATING): *********    . 4.
. 5.  BUILDING ENERGY CONSUMPTION WITHOUT SOLAR($)                      *********     . 5.
. 6.  BUILDING ENERGY CONSUMPTION WITH SOLAR($):                        ********      . 6.
. 7.                                                                                  . 7.
. 8. COMMENTS:  *************************************************************         . 8.
. 9.                                                                                  . 9.
.20.                                                                                  .20.
. 1.                                                                                  . 1.
. 2.                                     CONTROL FILE: SOLD ; SCREEN:SOLA             . 2.
. 3. ROWS 23 AND 24 ARE RESERVED FOR DATA ENTRY MESSAGES.                             . 3.
. 4.                                                                                  . 4.
.  .                                                                                  .  .
.........................................................................................
....         1         2         3         4         5         6         7         8 ....
.... 12345678901234567890123456789012345678901234567890123456789012345678901234567890 ....
.........................................................................................
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ONTROL FILE: SOLD

RECORD SIZE: 0230

OPERATION	ALLOWED?
FILE REPORT	YES
RECORD UPDATE	YES
RECORD DELETION	YES

DESCRIPTION: BASE WHERE SOLAR APPLICATION IS BEING CONSIDERED.

FIELD NAME	START POSN	INT FMT	INT LEN	EXT LEN	REP LEN	DEC POS	OCCUR COUNT	REPORT/ UPDATE	BLANK AFTER	DATE/ TIME	COM FIELD	VALID- ATION	ALIAS NAME
SOLBASE	1	C	[illegible]	[illegible]	[illegible]	0	1	R/U	YES				MILITARY INSTL OF SOLAR ANALYSI
SOLMAJ	[illegible]	C	3	3	3	0	1	R/U	YES				
SOLCOAL	1[illegible]	U	5	5	5	0	1	R/U	YES				COAL COST($/MBTU)(10.5?)
SOLELECT	17	U	5	5	5	0	1	R/U	YES				ELECTRICITY COST($/MBTU)(10.5?)
SOLFOC	2[illegible]	U	5	5	5	0	1	R/U	YES				FUEL OIL COST ($/MBTU)(10.5?)
SOLNGAS	27	U	5	5	5	0	1	R/U	YES				NATURAL GAS COST($/MBTU)(10.5?)
SOLOTHER	[illegible]	U	6	6	6	0	1	R/U	YES				OTHER FUEL COST($/MBTU)(10.6?)
SOLSIRAC	[illegible]	F	[illegible]	[illegible]	5	0	1	R/U	YES				COAL SIR(10.5)
SOLSIREC	[illegible]	F	[illegible]	[illegible]	3	0	1	R/U	YES				ELECTRICITY SIR(10.4)
SOLSIRAF	[illegible]	P	[illegible]	[illegible]	3	0		R/U	YES				FUEL OIL SIR(10.[illegible])
SOLSIRAO	50	F	[illegible]	[illegible]	5	0		R/U	YES				OTHER FUEL SIR(10.5)
SOLSIRAS	5[illegible]	F	[illegible]	[illegible]	5	0	1	R/U	YES				STEAM SIR (10.[illegible])
SOLSIRP	[illegible]	F	[illegible]	[illegible]	5	0	1	R/U	YES				PASSIVE SOLAR SIR(10.?)
SOLSTEAM	[illegible]	U	5	5	5	0	1	R/U	YES				STEAM COST($/MBTU)(10.5?)
SOLINSOL	67	U	[illegible]	3	[illegible]	0	1	R/U	YES				INSOLIAN AVG DAILY LANGLEY(125)
SOLSIRNN	7[illegible]	F	[illegible]	[illegible]	5	0	1	R/U	YES				NATURAL GAS SIR(10.?)
SOLCOM1	7[illegible]	C	60	60	60	0	1	R/U	YES				SOLAR COMMENTS
SOLCOM2	13[illegible]	C	60	60	60	0	1	R/U	YES				SOLAR COMMENTS
SOLFY	1[illegible]	F	[illegible]	[illegible]	3	0	1	R/U	YES				FISCAL YEAR FOR SOLAR APPLICA

MAJCOM

Preliminary Assessment-Unique Passive Solar Applications

1. Introduction. This is a quick, simple asseessment procedure for unique passive solar applications to be used only during the project development stage. It combines Congressional life cycle costing with engineering analysis to indicate the relative potential of daylighting and/or passive solar heating or cooling at each base, according to fuel cost.

2. General. The MAJCOM will calculate for each base, the savings to investment ratio (SIR) according to the following basic equation:

$$SIR = [(.00001 \times AxBxCxD) + (.00205\ xExD)\ (.0054\ xFxD) + .05]/1.30$$

A= Heating Degree Days (HDD)
B= Cost of heating fuel ($ per MBTU)
C= Solar Savings Fraction (SSF) from DOE Passive Solar Design Manual Vol 3, Page 18
D= Uniform Present Worth Factor (UPNF)
E= Cost of electricity ($ per MBTU using 3413BTU/KW)
F= Demand Charge

Assumptions:

a. Utilizes heating constant of 10BTU/HDD-SF-YR

b. Lighting consumption of 2.5 watts/SF

c. Lighting reduction potential of 3 to 10% as described in Renewable Energy Technology Handbook for Miltary Engineers

d. Maintenance cost savings of $0.05/SF

e. Construction cost additive of $2.00/SF which discounts 10% to $1.80.

f. Best available information on Peak Charges from current utility contracts.

3. Procedure -

a. The MAJCOM is to perform the preliminary analysis per Para 4 for each of its bases to determine if additional funds should be programmed for proposed facilities.

The results of the analyses will be input into the PDC inp creen SOLR (Atch 2). The PDC solar control file is BSOL (A: 3). If the PDC is not in operation, copies of the analyse. ll be sent to LEEEU and HQ AFESC/DEB. The bases should ade aware of these results so they can adjust the project grammed amounts of the Command Submittals.

c. I the SIR is one or greater for a particular base, then the base MAJCOM must screen all proposed facilities to determine which will require comprehensive passive solar analyses during the design process. The programmed amount must be adjusted in the Command Submittal to include the "Passive Solar Application."

d. The Base or MAJCOM must also include the unique passive solar requirement in the Project Booklet. The feasibility assessment SIR value must also be included to validate the solar requirement.

4. Sample Calculation.

For Barksdale AFB:

DOE Region: 6 HDD: 2337
UPWF: ELECT 14.40 DOE SSF: .65
GAS 17.45

FY83 COST/MBTU: ELECT $9.18
(USE LATEST) GAS $4.68

a. Annual Heating Consumption

10BTU/HDD/SF/YR x 2337 HDD = 0.0234 MBTU/SF/YR
(Given)

b. Annual Lighting Consumption

(1) 50 ft-candles/SF at 3ft ht = 2.5 Watts/SF

(2) 2.5 Watts/SF x 1KW/1000 Watts x 10 hrs/day x 300 days/yr = 7.5 KWH/yr/SF

(3) 7.5 KWH/yr/SF x 3413 BTU/KWH = 0.0256 MBTU/SF/yr

(4) Per DOE and Renewable Energy Manual, an 8% reduction in lighting can be achieved. Therefore, Savings = 0.0256 MBTU/SF/yr x 0.08 = 00205 MBTU/SF/yr

c. Peak Demand Reduction

(1) Due to lighting reduction: 2.5 Watts/SF x .08 = .0002 KW/SF/Mo.

(2) Due to HVAC size reduction: Assume 10% reduction in equipment sizing. Locations farther north (>5000 HDD) would achieve comparable reductions (e.g. 5% reduction in A/C...etc)

(3) For A/C, use 400SF/TON and 1 KW/TON = .00025 KW/SF

(4) Total Peak Reduction = 0.0002KW/SF/MO + 0.00025KW/SF/MO = 0.00045 KW/SF/MO

d. Maintenance Savings

Due to reduction of mechanical and lighting equipment sizing, savings will be accumulated over the building life. There should be less service calls and less replacement of equipment components. For purpose of the preliminary analysis, the 25 year life savings will be assumed at $0.05/SF.

e. 25 Year Life Solar Savings

(1) Heating: 0.0234 MBTU/SF/yr x 0.65 (SSF) x 4.68 (FUEL COST) x 17.45 (UPWF) = $1.24/SF

(2) Lighting: 0.00205 MBTU/SF/yr x 9.13 (FUEL COST) x 14.40 (UPWF) = 0.27/SF

(3) Peak Demand: .00045 KW/SF/MO x 4 ($/KW) x 12 MO (ANN.SAV.) x 14.40 + .31/SF

(4) Maintenance = .05/SF

(5) Total Savings =$1.87/SF

f. SIR Calculation

(1) Additive construction cost for unique passive solar = $2.00/SF

(2) Construction Cost after 10% investment credit = $1.80/SF

(3) SIR = 1.87/1.30 = 1.04

g. Conclusion

Unique passive solar programmed amounts can be added to proposed projects at their base for further evaluation by the designer. The proposed facilities which must include passive solar applications will be determined by the Base or MAJCOM.

DESIGN CRITERIA
UNIQUE PASSIVE SOLAR ANALYSIS

1. Economic Analysis

a. A solar energy system for a facility shall be considered cost effective if the difference between the original investment cost of the energy system for the facility with a solar energy system and the original investment cost of the energy system for the facility without a solar energy system can be recovered over the expected life of the facility.

b. The determination of whether a cost differential can be recovered over the expected life of a facility shall be made using the life cost analysis procedure implemented by the National Bureau of Standards (NBS) Handbook 135 "Life-Cycle Cost Manual for the Federal Energy Management Program." This procedure shall include:

(1) No maintenance expenses, if determined to be part of normal building or ground maintenance over the expected life of the facility or during a period of 25 years, whichever is shorter.

(2) Actual fossil fuel costs at the facility with a rate of growth IAW latest DOE tables published in the Federal Register. Otherwise use those in the 13 November 1981, Federal Register and included in attachment No. 1. Overseas locations shall use values derived from the tables given for the United states average.

(3) A discount rate of 7 percent per year for all expenses of the energy system.

(4) Note: Do not size the solar system to accomodate standby power.

c. Reduce the original investment cost of the solar energy system by 10 percent to reflect an allowance for an investment cost credit.

2. System Performance Parameters. The unique passive solar system shall be optimized based on the highest net life cycle savings to investment ratio (SIR). However, the size must provide not less than 25 percent of the required space heating or cooling nor less than 35 percent of lighting (year round basic).

3. Types of Systems. The designer must concentrate his efforts on daylighting, thermal mass storage, and passive solar cooling systems. However, he may include other unique passive solar applications (Ref ETL: Unique Passive Solar Systems) if cost effective.

4. Architectural Compatibility. Whether interior or exterior, application shall be designed to be architecturally compatible with the total environment.

5. Type of Analysis.

a. The passive solar application(s) will be evaluated by the designer prior to the 30 percent design stage. The solar analysis can be "BLAST" or similar analysis and must include energy data for solar heating derived from DOE's Passive Solar Design Handbooks Vol I, dated January 1980 (DOE/CS-0127/1&2), Vol III, dated July 1982 (DOE/CS-0127/3), and Solar Design Workbook dated June 1981 (SERI/SP-62-308) These manuals can be obtained through NTIS, U.S. Dept. of Commerce 5285 Port Royal Rd. Springfield, Va 22161. The computer analysis must also incorporate energy data for daylighting from established procedures. One source for daylighting quantification is booklet "How to Predict Interior Daylight Illumination" from Libbey-Owens-Ford Co., 811 Madison Ave, Toledo, Ohio 43695.

6. Weather Data. Reference data for active solar applications, Atch 4(2 of 2).

7. Cost Effective. If the solar system is cost effective, the designer will provide the PDC input data per Atch 9 at the 30 percent design state. The design of the passive solar system can then proceed to the 100% design stage. At the final stage of design, the designer will furnish any updated information for the PDC.

8. Not Cost Effective. The cost effectiveness of the application(s) must be determined early in the design stage, preferrably the concept stage. The designer must still provide the information per Atch 9 at the 30 percent design stage. Further design of the solar system will then be terminated.

Appendix B: ETL 82-7

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C. 20332

30 NOV 1982

LEEEU

Engineering Technical Letter 82-7: Unique Passive Solar Applications

HQ AAC/DEE	HQ AFSC/DEE	HQ MAC/DEE	HQ AFCC/DEO
HQ ATC/DEE	HQ TAC/DEE	HQ AFLC/DEE	HQ SAC/DEE/DEER
HQ PACAF/DEE	HQ AFRES/DEE	HQ ESC/DEE	HQ USAFE/DEE/DEER
HQ USAFA/DEE	HQ AFCOMS/DEE	AFIT/DEE	AFMPC/MPCSXC
SPACECOM/DEE	NGB/DEE	AFRCE/CR	AFRCE/ER
AFRCE/WR	AFRCE/M-X		

1. Purpose: This letter provides a detailed description of unique passive solar applications. The guidance to incorporate these applications in the design process was provided in ETL 82-5.

2. Description: Any application which is intended to provide solar heating, solar cooling, or daylighting through passive means is to be considered a unique passive solar application. These type applications require additional analysis, structure and funds, and must be proven cost effective IAW Congressional guidelines. Reference the following manuals for details of solar energy fundamentals, technology, systems, and components: DOE Facilities Solar Design Handbook dated January 1978, no. DOE/AD-0006/1; Passive Solar Design Handbook, Volume One and Volume Two, dated January 1980, nos. DOE/CS-0127/1&2; and Solar Design Workbook, dated June 1981, no. SERI/SP-62-308 (manuals are available through National Technical Information Service (NTIS), U. S. Dept. of Commerce, 5285 Port Royal Rd., Springfield, Virginia 22161). These applications consist of:

a. Direct Gain. This approach includes the direct heating of working areas by solar energy. These areas contain a mass for absorbing and storing daytime heat. Usually, there is an expanse of south facing glass which is exposed to the maximum amount of solar energy in winter and minimum in summer. This approach lends itself best for heating hallways and sunspaces where the storage mass is within twelve feet of the glass area.

b. Indirect Gain. This approach is best suited for heating office or living areas because direct sunlight and glare can be avoided. Sunlight is absorbed and stored by a mass between the glazing and the conditioned space. Examples of the indirect

approach are the thermal storage wall, thermal storage roof, and the room adjacent to an attached sunspace.

c. Isolated. This is an indirect system except that there is a distinct thermal separation (either by insulation or physical) between the thermal storage and the heated space. The convective loop, solar chimney, or induced stacks fall in this category. The thermal storage wall, thermal storage roof, and attached sunspace approaches can also be made into isolated systems by insulating between thermal storage and the heated space.

d. Masonry Thermal Storage. Materials used for this type storage include concrete, concrete block, brick, stone, and adobe, either individually or in various combinations. To minimize indoor temperature fluctuations, construct interior thermal storage walls and floors with a minimum of 6 inch thickness. Walls or floors which are to be used for heat storage must have a dark colored finish. Do not use carpeting on masonry floors which are to be used for storage. Usually one-half to two-thirds of the total surface of the controlled space is constructed of 6 to 8 inches of masonry.

e. Water Thermal Storage. Water is usually contained in only one wall of a space. This wall is exposed to direct sunlight most of the day. Materials commonly used to construct the wall are plastic or metal containers.

f. Phase-Change Storage. This type storage has the ability to store a large amount of heat in a small space. Calcium chloride hexahydrate is a widely used material which changes state from solid to liquid when its temperature reaches approximately 80°F. It has approximately four times the heat storage capacity of water and eight times that of rock or masonry. Metal containers must be treated to resist corrosion reaction. Plastic or fiberglass containers do not risk corrosion but are less thermally conductive than metals.

g. Attached Sunspaces (Greenhouses). This system combines both direct gain and thermal storage wall or floor. The back wall or floor of the sunspace converts sunlight into heat. This heat is then transferred by radiation, conduction, and convection to within the sunspace and into the rest of the building with proper design. Fans may be used to improve heat transfer to adjoining spaces. For best results, the storage wall must be within 12 feet from the glazed wall.

h. Solar Chimney. Plenum, flue or chimney stack is painted black or a dark color and is exposed to direct sunlight. As the dark area temperature rises, the self-induced air movement within the chimney increases. This action provides ventilation by thermosyphoning. Hot or warm air is removed from the building. This

is not an efficient system because heat removal from mass by air is not very effective. The efficiency of the system is limited to small structures where ventilation inlets and outlets are in close proximity.

i. King Ventilation System. Air flow is the reverse of the solar chimney and is intended for winter use. Cold air is exhausted at floor level while warmer air is let in at the top of the room or stack. This is not an efficient system. Additional energy must be used to heat makeup air. This application is limited to environments that can tolerate wide temperature swings.

j. Earth Tubes. Cool air in summer and warm air in winter is drawn into a building from a pipe buried five to ten feet below ground level taking advantage of the long time delay differences between above and below ground temperatures. This method is subject to noise transmission, moisture and fungus buildup.

k. Atrium. This is a central court, a hall or an entrance court to provide pedestrian traffic flow between offices or departments, a leisure greenhouse environment, daylighting for inner perimeter office space, or a natural draft ventilation as warm air rises.

l. Roof Ponds. The thermal mass is located on the roof of the building. Water is enclosed in thin plastic bags and supported by a roof deck with additional structure. In winter, the ponds are exposed to sunlight during the day and then covered with insulating panels at night. In summer, the panel positions are reversed, covering the ponds during the day to protect them from the sun and heat, while removing them at night to allow the ponds to be cooled by natural convection and by evaporation to the cool night sky. Problems still remain with the closing and opening of the roof insulation.

m. Convective Loop. The major components of this system include a flat plate collector and heat storage tank. Two types of heat transfer and storage medium are used: a liquid or air with rock storage. As the liquid or air in a collector is heated by sunlight, it rises and enters the top of the storage tank, while simultaneously pulling cooler liquid or air from the bottom of the tank into the collector. This natural convection current continues as long as the sun shines. When air with rock storage is used, the system is subject to moisture, fungus, and mildew growth, unless it is a closed system.

n. Breathing Wall. Hollow masonry tiles are used on large eastern and western walls. The "Wall" will act as a solar shading device and reduce heat transmission from the outer wall

element to the interior wall element. The hollow ventilating tiles serve as a flue through which air circulates vertically between open joints and is intended to reduce heat transmission from the outer wall to the inner wall. This application can present a fire safety problem.

o. Daylighting. Any window area greater than 15% of the area being served will require an economic analysis to prove its cost effectiveness. The maximum depth of the area being served will be 20 feet measured from the exterior wall.

p. Hybrid Systems. Combinations of active and passive applications are referred to as "hybrid" systems. A common example is the use of a passive collector such as a greenhouse in conjunction with a fan-forced rock bed thermal storage.

FOR THE CHIEF OF STAFF

Harold L. Korntved for
G. [illegible] MYERS III
Chief, [illegible]
Engineering Construction Division
Directorate of Engineering & Services

cc: HQ AFESC/CA
COE/DAEN-MPC-F
NAVFAC/Code 052

Appendix C: ETL 82-6

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C. 20332

REPLY TO ATTN OF: LEEEU

30 DEC 1982

SUBJECT: Engineering Technical Letter 82-6: Normal Passive Solar Applications

TO: HQ AAC/DEE, HQ AFSC/DEE, HQ MAC/DEE, HQ AFCC/DEO, HQ ATC/DEE, HQ TAC/DEE, HQ AFLC/DEE, HQ SAC/DEE/DEER, HQ PACAF/DEE, HQ AFRES/DEE, HQ ESC/DEE, SPACECOM/DEE, HQ USAFA/DEE, HQ AFCOMS/DEE, AFIT/DEE, AFMPC/MPCSXC, NGB/DEE, AFRCE/CR, AFRCE/ER, AFRCE/WR, AFRCE/MX, HQ USAFE/DEE/DEER

1. This letter:

a. Provides detailed descriptions of normal passive solar applications which must be considered in any design.

b. Establishes design development and building design requirements for the A-E, the MAJCOM and/or the Base engineering staff.

c. Establishes information that the A-E must provide at the concept and 35% design stages.

d. Is effective immediately.

2. Intent. Energy efficient design, whether of a new facility or retrofit of an existing facility, must satisfy the requirements for human comfort and safety, building protection and aesthetics, and equipment operating enviroment within a limited funding budget and stringent DOD and Congressional energy constraints. An energy efficient design must include consideration of normal passive solar applications described in this letter, except as noted. Normal passive solar applications do not require a special economic analysis for justification and should be part of the programmed amount.

3. Design Development Considerations. These guidelines are to be utilized by:

a. The Base and/or MAJCOM during master planning and project booklet development.

b. The A-E during the concept design stage.

4. Normal Passive Solar Applications. Following is a description of normal passive solar applications.

(3) Orientation of Nonair-Conditioned-Buildings. The preceding orientation criteria also apply to buildings not initially air-conditioned that are likely to be air-conditioned sometime within their useful life.

c. Building Shape.

(1) General. To take advantage of the sun in climates where solar heating, cooling, and/or lighting can be used, the HDD must exceed 3000 for heating, or cooling degree days (CDD) must exceed 2000 for cooling and insolation must exceed an annual average 300 Langleys per day. Maximum solar energy will be available between 0900 and 1500 hours (winter or summer). An elongated building along the east-west axis, in most climates where the insolation exceeds an annual average 300 Langleys per day will minimize heating, cooling and electric lighting requirements.

(2) Building Configurations. Building envelope heat loss or heat gain can be minimized by minimizing the ratio of building wall and roof area to building floor area. This ratio essentially is a function of length to width (aspect ratio) and the height or the number of stories of the building. This ratio can be minimized by constructing the building partially or totally below grade. Reference Navy Document, Interim Design Criteria, January 1975, Section 1, for building geometry considerations.

(3) Zoning Energy Analysis.

(a) The floor plan of every multi-function (minimum of 3) or multistory facility must include consideration for energy consumption of each function to determine which are best located along the south and north walls. At locations where the HDD exceed 3000 and insolation exceeds an annual average 300 Langleys per day, location of functions requiring the most heating should be located along the south wall. Functions requiring the most lighting should be located along the south wall in the northern hemisphere and north wall in the southern hemisphere. A computer analysis may be required to optimize locations of the different functions.

(b) Location of interior spaces (zoning) according to need of heating and lighting. Interior spaces can be supplied with much of their heating and lighting requirements by placing them along the south face of the building, thus taking advantage of the sun's energy during the day. Consider placing rooms to

a. Siting. Siting is to be accomplished in accordance with (IAW) AFM 86-6. It is important to determine in advance whether evergreen trees and shrubs or neighboring structures shade the southern side of the facility during winter months between 0900 and 1500 hours because during these hours, solar energy is at its maximum for solar heating and/or daylighting. This applies especially to those areas where heating degree days (HDD) exceed 3000 and insolation is greater than an annual average 300 Langleys per day (3.69 Langleys = 1 TU per SF). Reference "Insolation Data Manual" No. SERI/SP-755-789, Oct 1980, for insolation values of different sites.

b. Orientation.

(1) General. Building orientation is to be done IAW guidelines in AFM 86-6. The orientation for maximum solar gain is with the long walls of the facility facing north and south. South walls may vary up to 30 degrees from true south and still receive more than 90 percent of the sun's available energy. At 45 degrees variation, the south wall will receive approximately 75 percent of available solar energy.

(2) Orientation of Air-Conditioned Buildings. In order to reduce the initial costs and lifetime operating costs of air-conditioning equipment, all new buildings which are eligible for air-conditioning either wholly or in part shall be sited so that the long axis of the building is along an east-west axis within 45 degrees. Deviations are authorized only if:

(a) Detailed solar studies prove that an alternate orientation is less energy intensive over the entire year.

(b) The site's topography prevents the proper orientation and there is no alternate site. The term "topography" does not cover siting constraints created solely by existing utility lines, roads, parking areas, and nearby buildings.

(c) A building is to be heated by solar energy and an alternate orientation is required for maximum solar efficiency, such as, placing the smallest wall area against a winter, prevailing wind of 7 MPH or more.

(d) Mission requirements dictate an alternate orientation.

(e) The new building is an integral part of a complex of existing facilities such as a community center.

any day of the year.

(6) In vacant land which will be developed, solar envelopes should be developed for each proposed building to ensure adequate sun accessibility for each. A solar envelope is defined as an imaginary container derived from the sun's relative daily and seasonal movement. Within this container, a building can be constructed with the assurance that it will not cast shadows on designated portions of adjoining buildings. Reference Solar Design Workbook, June 1981. No. SERI/SP-62-308 Chapter 4, and ASHRAE Book of Fundamentals, Chapter 26 for solar altitude and azimuth angles for various latitudes and dates throughout the year.

e. Daylighting or Clerestories.

(1) General. Locate major window openings to the southeast, south and southwest according to the sunlight requirements of each space. When possible, recess windows to better control heat gain or loss. In regions where the HDD exceed 3,000 and annual average solar energy exceeds 300 Langleys per day, glass areas along the east, west, and especially the north side of the building will not exceed 10% of the floor area served, except 5% if the area consists of hallways, toilet or storage. The floor area served is to be limited to a depth of twenty feet measured from the exterior wall. The glass along the south wall can be up to 15% of the floor area served. Where the HDD is less than 3000 and the CDD less than 2000, glass areas along north and south walls can be up to 15% of the floor area served. If the annual average solar energy is less than 300 Langleys per day and the HDD exceeds 5000, limit all glass areas to 7% of floor area served. Consider double pane glass up to 5000 HDD and triple pane for greater than 5000 HDD.

(2) Storm Sash and Doors or Insulating Glass. Use of these items in all windows (includes fixed and skylights) and in all glazed sections of all exterior doors, is mandatory in buildings heated to 65°F in those areas where the HDD is 3000 or more. Studies shall be made in other climatic zones to determine whether insulating glass, double or triple glazing or storm sash is cost effective in any new facility on a life cycle cost basis in accordance with the National Bureau of Standards Handbook 135. Where economically feasible insulating glass, double or triple glazing or storm sash shall be used.

(3) Daylighting and Ventilation:

the southeast, south and southwest, according to their requirement for solar energy. Those spaces having minimal heating and lighting requirements such as corridors, closets, mechanical rooms, and toilets, when placed along the north face of the building, will serve as a buffer between the heated spaces and the colder north face. This requirement applies mainly to areas where the HDD exceed 3000.

(4) In applying the above "long axis" criteria to the design of buildings with wings, such as "L" or "E" shaped buildings, make a careful analysis of solar loading to determine whether the sum of the loads on the wings is greater than the load on the main area. In such cases, the wings shall be oriented in the east-west plane.

d. Spacing of Facilities. Solar irradiation to adjacent proposed or existing buildings must be guaranteed to encourage solar applications in these buildings with future retrofit projects. The following rules are recommended to support solar considerations. They were derived from Solar Envelope Concepts, Final Report, April 1980, SERI/SP-98155-1.

(1) Solar irradiation should be available for any building at least 6 hours per day in order to provide energy that is sufficient for active or passive solar applications. These hours are to be between 0900 and 1500 hours at all times of the year.

(2) To protect solar collector plates that might be installed in the future on any nearby roof, the shadow of a new or proposed facility or addition cannot extend above the roof parapet of any existing facility during the above specified hours of the day.

(3) Land with temporary facilities may be considered as vacant land. Temporary facilities are those described in AFM 88-15, Chapter 19.

(4) Fire walls or walls without windows, which will not be considered as heat storage mass in future projects, may be totally shaded by new facilities.

(5) Walls of nearby buildings that function as window walls or that have window openings that exceed 25% of the wall area may be partially shaded by a new facility provided that no more than 33% of the wall is shaded during the specified hours of

color. Shading devices or translucent panels may be used to eliminate glare, particularly in work areas.

(g) Shading Devices.

(1) General. Proper solar screening reduces solar heat gain during summer months, regulates solar daylighting and allows direct solar energy for solar heating or storage during winter months. Proper design of solar screening includes consideration of latitude, elevation, orientation, percent of glass, heating and cooling loads, obstruction and inconveniences to such activities as window washing. Consider roof overhangs, horizontal and vertical building projections, louvers, or reflective glass coating, internal shades, venetian blinds, movable insulation, insulating curtains or draperies, eyebrow reveals, or vertical/horizontal fins.

(2) Solar Shading in Air Conditioned Buildings:

(a) For any building eligible for air conditioning, all windows and other glazed areas exposed to the sun (includes all glass in the orientation 45° from an east-west axis shall be completely shaded on the exterior no less than 80 percent of the time between 0800 and 1600 (solar time) daily during the period from June 1 through September 30. Partial shading all the time is an acceptable alternative provided the total solar gain does not exceed that achieved by compliance with criteria noted above, based on actual solar studies.

(b) Shading may be achieved by building projections (either horizontal or vertical), deep reveals, or any combination of these measures. Also,solar shading may be achieved through the use of external solar screens, either fiberglass or metal, which completely shade the glass area and have a solar heat rejection of no less than 70 percent.

(c) The use of fully reflective glass as manufactured in the factory is also acceptable for solar shading. The use of "heat-absorbing tinted glass" and partial exterior shading is acceptable provided the total heat gain, based on specific studies, does not exceed that permitted under the criteria noted above. Films and coatings added to glass after manufacture are not acceptable.

h. Protected Entrances. In climates where HDD exceed 3000 or

(a) The following criteria establishes minimum sizes for glass areas in relation to floor areas and is to be followed to the extent that they do not conflict with the design criteria in other paragraphs.

(1) Whenever feasible, all habitable rooms will contain windows in exterior walls. Window areas equal to or exceeding 5 percent of the floor area will be operable for ventilating and cleaning, except the minimum will be 7 percent for offices and administrative areas of maintenance facilities. In shops and other maintenance facilities the glass area of windows in work spaces will comply with ANSI Standard A 11.1 and the design of the ventilation system shall conform to the recommendations of AFM 88-15 Chapter 6 or the Guide of the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

(2) For all facilities such as administrative, dormitories, classrooms, and patient bedrooms in hospitals, located where the HDD exceeds 5000 or where the summer CDD exceeds 2000 the glass area shall not exceed 7 percent of the floor area. For other facilities, fenestration shall be planned to take optimum advantage of natural light and ventilation with full consideration of the impact on the heating and air-conditioning load. In regions where other provisions are not made for cooling and ventilation, natural ventilation shall be used to a maximum degree consistent with local engineering practice and consideration of heating costs.

(b) Provide operable windows in exterior walls of dormitories, bachelor officer quarters, and bedrooms in hospitals. The sash, when fully opened, will allow for emergency egress. Fixed fenestration may be used in fully air-conditioned building areas, except in the above noted facilities, provided appropriate means for emergency egress are provided.

(c) Windows may be eliminated where there is a justifiable requirement for a fallout shelter or when advantageous to the functional use or special needs.

(d) Facilities which are located to meet quantity safety distances from explosives will have a minimum number of windows facing the explosive area.

f. Skylighting. Skylighting refers to illumination provided from sunlight through windows in a horizontal roof plane. Limit skylighting to 5% of the roof area. Ceilings are to be a light

CDD exceed 2000, make the main pedestrian entrance to the building an enclosed space (vestibule or foyer) that provides a double entry or air lock between the building and the exterior. Where functionally possible, orient the entrance away from the prevailing winter or summer winds or provide a windbreak to reduce infiltration. The inside and outside doors may be offset from each other or at right angles to each other for maximum effectiveness. If vestibules cannot be installed, consider using revolving doors in conjunction with emergency exit fire doors.

i. Landscaping. Consider trees or tall hedges to provide shading for east and west facing glass to block the low early morning and late afternoon sunlight. Deciduous trees or tall hedges along a south wall could also be used for shading during the summer months. These can allow solar energy for heating during winter months. Also consider tall hedges or trees between asphalt parking areas and buildings to reduce heat gain during summer months. In regions where HDD exceeds 5000, and the annual wind speed averages more than 7MPH consider evergreens along winter prevailing wind side of the building for windbreaks.

j. Insulation is to be done IAW, Change 10 to General D.I. No.1 and AFM 85-18 design criteria.

k. Berming. Consider constructing facilities partially below grade. For buildings in climates of 5000 HDD or more where the average winter wind speed exceeds 7mph, consider berming the entire winter prevailing wind wall side of single story buildings or the entire first floor of multi-story buildings. Berming will enable sunlight availability at the north side of a one story building during winter months and will reduce heat loss through the wall. In summer, it will reduce heat gain. Ground temperatures are higher in winter and lower in summer than ambient. In climates where HDD exceeds 8,000 consider earth sheltered buildings. Reference the Navy's NAVFAC DMI series design manual for earth sheltered facilities.

5. A-E Submittals: The following information will be required from the A-E for all new building designs:

(a) At 20% Concept Stage:

(1) An analysis of energy efficiency due to proposed building siting and orientation.

(2) Three building configurations to reduce or elimi-

nate solar shading of adjacent facilities IAW para 2c, when applicable.

(3) A discussion regarding the ratio of building wall and roof areas to building floor area with regard to energy efficiency, IAW Para 2d.

(b) At 35% Concept Stage:

(1) Results of active solar application study when applicable.

(2) Results of unique passive solar application study, when applicable.

(3) Summary of zoning energy analysis showing heating, cooling, and/or lighting energy consumed by each department or function and discussion of location of each along north or south walls according to this analysis. Reference Para 4c(3).

(4) A breakdown of the calculated energy budget figure (EBF) into heating, cooling, ventilation, lighting and water heating budgets. The A-E must also provide the number of operating hours that the total EBF was based upon.

(5) Recommendations on how to reduce further the particular calculated energy budget when it is 35% or more of the total energy budget.

FOR THE CHIEF OF STAFF

G. HAMMOND MYERS, III
Chief, Utilities Branch
Engineering Construction Division
Directorate of Engineering & Services

cc: HQ AFESC/CV
COE/DAEN-MPC-F
NAVFAC/Code 052

Appendix D: ETL 83-9

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, D.C.

LEEEU

14 NOV 1983

Engineering Technical Letter 83-9: Insulation

ALMAJCOM/DEE SPACECOM/DEE AFRCE/WR AFRCE/ER AFRCE/CR AFRCE/SAC AFRCE/BMS HQ SAC/DEER HQ AFCC/DEO

1. Purpose: This letter:

a. Provides maximum transmission values ("U").

b. Establishes requirements for optimum insulation in all new or existing Air Force "defense-owned" facilities.

c. Supersedes insulation criteria in Change 10 to the General DI No 1, dated 25 May 1982.

2. Requirements: This guidance:

a. Pertains to design of new facilities, additions to or renovations of existing facilities which are heated and/or cooled with mechanical systems.

b. Is mandatory.

c. Is applicable starting with those projects not yet 30% designed as of the date of this letter.

3. Discussion: When the envelope (exterior walls) of an existing building will be altered to improve energy efficiency then these "U" values will pertain. Insulation values for all types of design will be optimized using a computerized energy analysis in accordance with (IAW) Engineering Technical Letter (ETL): Computer Energy Analyses. This is to ensure that the design energy budget meets or is less than DOD's Energy Budget Figures, IAW ETL: Energy Budget Figures.

4. Design Criteria:

a. Heat gain calculations shall be IAW the current edition of the ASHRAE Handbook of Fundamentals, as a minimum.

b. The inside design temperatures for personnel comfort shall be IAW AFM 88-15, Chapters 5 and 6. The design relative humidity will be 50 percent minimum or equal to the

outside air dewpoint [illegible] temperature [illegible] however is low provided that no net [illegible] consumed [illegible] the humidity control. Recovered [illegible] heat [illegible] for heating domestic [illegible] used [illegible]. [illegible] around system may also be [illegible] for pre[illegible] outside air.

c. All new air conditioned or heated facilities will [illegible] constructed to meet the maximum heat transmission values [illegible] of Table 1, unless a rigorous engineering analysis shows [illegible] another "U" factor is more energy efficient and cost effective. The minimum requirement is that design energy budget figure must not exceed the required energy budget figure.

FOR THE CHIEF OF STAFF

G. HAMMOND MYERS, III
Chief, Utilities Branch
Engineering Construction Division
Directorate of Engineering & Services

2 Atch
1. Table 1 Maximum Insulation Values
2. Index, 10 Nov 83

cc: HQ USAF/LEEC
HQ USAF/LEEH
HQ AFESC/CA
DAEN-ECE-S
NAVFAC/CODE 052
DASD (I)
AAFES/EN
AFMPC/MPCSXC
NGB/DEE

TABLE 1

MAXIMUM INS[illegible] ("U") VALUES						
HEATING DEGREE DAYS	GROSS WALLS[2]		WALLS	CEILING/ROOF	FLOOR	
°F DAYS (°C DAYS)	U_o[3]	U_o[4]	U_w[5]	U_R[6]	U_F[7]	U_F[8]
Less than 1000 (Less than 560)	0.31 (1.760)	0.38 (2.15)	0.15 (0.853)	0.05 (0.284)	0.10 (0.568)	[illegible] ([illegible])
1000-2000 (561-1110)	0.23 (1.306)	0.38 (2.[illegible])	0.15 90.853)	0.05 (0.284)	0.08 (0.454)	0.24 (1.26[illegible])
2001-3000 (1111-1670)	0.18 (1.022)	0.36 (2.048)	0.10 (0.568)	0.04 (0.227)	0.07 (0.397)	0.21 (1.192)
3001-4000 (1671-2220)	0.16 (0.909)	0.36 (2.048)	0.10 (0.568)	0.03 (0.170)	0.07 (0.397)	0.18 (1.022)
4001-6000 (2221-3330)	0.13 (0.738)	0.31 (1.760)	0.08 (0.454)	0.03 (0.[illegible]70)	0.05 (0.284)	0.14 (0.794)
5001-8000 (3331-4440)	0.12 (0.683)	0.28 (1.590)	0.07 (0.397)	0.03 (0.170)	0.05 (0.284)	0.12 (0.683)
Over 8001 (Over 4441)	0.10 (0.568)	0.28 (1.59)	0.07 (0.397)	0.03 (0.170)	0.05 (.284)	0.10 (0.568)

ATCH I

FOOTNOTES:

1. Heat transmission values are expressed in English unit (U=BTU-ft-h-°F). Values shown in parenthesis are expressed in SI units (U=W/m-°K).

2. Gross Wall "U_o" values include all doors and windows, window frames, metal ties through walls, structural steel members that protrude through all insulation to the exterior or adjacent to the exterior, and continuous concrete or masonry walls or floors that extend from inside heated spaces through the building envelope to the exterior, e.g., fire walls that extend above the roof and concrete floor slabs that extend beyond the exterior wall to form a balcony or terrace. Greater areas of glass are acceptable if any energy analysis shows daylighting and/or passive solar heating will reduce significantly fossil fuel derived energy; The design energy budget figure must also be within the required EBF.

3. Gross wall "U_o" values are to be used for all new construction and major alterations of facilities other than hospital, medical and dental clinics.

4. Gross Wall "U_o" values are to be used for hospital and medical/dental facilities. Maximum "Uo" value will put a limitation on the allowable percentage of glass to gross wall area in a building. Insulating glass on the building will allow higher percentage of glass in comparison with single glass.

5. Wall "U_w" value is the thermal transmittance of all elements of the opaque wall area. "U_w" values are to be used for upgrade of existing facilities where the alteration of walls and resizing of window glazing to meet gross wall values is not cost effective.

6. Ceiling/Roof "U_r" values are for ceiling/roof areas where adequate space exists for insulation to be applied above ceiling and/or below roof structure. Built-up roof assemblies and ceiling assemblies in which the finished interior surface is essentially the underside of the roofdeck shall have a maximum "U " value of 0.05 (0.284) for any Heating Degree Day area.

7. Floor "U_f" values are for floors of heated space over unheated areas such as garages, crawl space and basements without a positive heat supply to maintain a minimum of 50°F (10°C).

8. Floor "U_f" values are for slab-on-grade insulation around the perimeter of the floor.

Appendix E: Air Force Installation Solar Design Data

Installation	Closest City	Climate Region	Rwall Lo	Rwall Hi	(Ac/Af)o Lo	(Ac/Af)o Hi
Altus	Wichita Falls TX	HA	20	25	15	18
Andrews	Washington DC	HA	20	25	6	9
Arnold	Chattanooga TN	HA	20	25	6	9
Barksdale	Shreveport LA	MO	15	20	9	12
Beale	Red Bluff	MO	15	20	12	15
Bergstrom	Austin TX	MO	15	20	9	12
Blytheville	Memphis TN	HA	20	25	9	12
Bolling	Washington DC	HA	20	25	6	9
Brooks	San Antonio TX	MO	15	20	9	12
Cannon	Tucumcari NM	MO	15	20	18	21
Carswell	Fort Worth TX	MO	15	20	9	12
Castle	Fresno CA	MO	15	20	12	15
Chanute	Springfield IL	VH	25	30	6	9
Charleston	Charleston SC	MO	15	20	9	12
Columbus	Birmingham AL	MO	15	20	9	12
Davis-Monthan	Tucson AZ	MI	10	15	15	18
Dover	Wilmington DE	HA	20	25	6	9
Dyess	Abilene TX	MO	15	20	12	15
Edwards	Daggett CA	MI	10	15	12	15
Eglin	Mobile AL	MO	15	20	9	12
Ellsworth	Rapid City SD	HA	20	25	12	15
England	Baton Rouge LA	MO	15	20	9	12
Fairchild	Spokane WA	HA	20	25	6	9
Francis Warren	Cheyenne WY	HA	20	25	18	21
George	Daggett CA	MI	10	15	12	15
Goodfellow	San Angelo TX	MO	15	20	12	15
Grand Forks	Minot ND	VH	25	30	8	12
Griffiss	Syracuse NY	VH	25	30	3	6
Grissom	Fort Wayne IN	VH	25	30	3	6
Gunter	Montgomery AL	MO	15	20	9	12
Hanscom	Boston MA	VH	25	30	6	9
Hill	Salt Lake City UT	HA	20	25	15	18
Holloman	Truth or Conseq NM	MO	15	20	18	21
Homestead	Miami FL	MI	10	15	6	9
Hurlburt	Mobile AL	MO	15	20	9	12
Indian Springs	Las Vegas NV	HA	20	25	18	21
Keelser	Mobile AL	MO	15	20	9	12
Kelly	San Antonio TX	MO	15	20	18	21
Kirtland	Albuquerque NM	MO	15	20	18	21
K. I. Sawyer	Sault Ste. Marie MI	VH	25	30	3	6
Lackland	San Antonio TX	MO	15	20	9	12
Langley	Norfolk VA	HA	20	25	9	12
Laughlin	Del Rio TX	MO	15	20	12	15

Appendix E (cont.): Air Force Installation Solar Design Data

Installation	Closest City	Climate Region	Rwall Lo	Rwall Hi	(Ac/Af)o Lo	(Ac/Af)o Hi
Little Rock	Little Rock AR	HA	20	25	9	12
Loring	Caribou ME	VH	25	30	3	6
Los Angles	Los Angles CA	MI	10	15	12	15
Lowry	Denver CO	HA	20	25	18	21
Luke	Phoenix AZ	MI	10	15	15	18
MacDill	Tampa FL	MI	10	15	9	12
Malstrom	Great Falls MT	VH	25	30	9	12
March	Los Angles CA	MI	10	15	12	15
Mather	Red Bluff CA	MO	15	20	12	15
Maxwell	Montgomery AL	MO	15	20	9	12
McChord	Seattle WA	HA	20	25	6	9
McClellan	Red Bluff CA	MO	15	20	12	15
McConnell	Dodge City KS	HA	20	25	12	15
McGuire	Philadelphia PA	HA	20	25	6	9
Minot	Minot ND	VH	25	30	6	9
Moody	Tallahassee FL	MO	15	20	9	12
Mountain Home	Boise ID	HA	20	25	12	15
Myrtle Beach	Chareston SC	MO	15	20	9	12
Nellis	Las Vegas NV	HA	20	25	18	21
Norton	Los Angles CA	MI	10	15	12	15
Offut	Omaha NE	HA	20	25	12	15
Patrick	Orlando FL	MI	10	15	9	12
Pease	Concord NH	VH	25	30	9	12
Petersen	Colorado Springs CO	HA	20	25	18	21
Plattsbugh	Burlington VT	VH	25	30	3	6
Pope	Raleigh NC	HA	20	25	9	12
Randolph	San Antonio TX	MO	15	20	9	12
Reese	Lubbock TX	MO	15	20	18	21
Robins	Macon GA	MO	15	20	9	12
Scott	St Louis MO	HA	20	25	9	12
Seymour-Johnson	Raleigh NC	HA	20	25	9	12
Shaw	Columbia SC	MO	15	20	9	12
Sheppard	Wichita Falls TX	MO	15	20	12	15
Tinker	Oklahoma City OK	HA	20	25	12	15
Travis	San Francisco CA	MO	15	20	9	12
Tyndall	Tallahassee FL	MO	15	20	9	12
USAF Academy	Colorado Srings CO	HA	20	25	18	21
Vance	Oklahoma City OK	HA	20	25	12	15
Vandenberg	Bakersfield CA	MI	10	15	12	15
Whiteman	Kansas City MO	HA	20	25	9	12
Williams	Phoenix AZ	MI	10	15	15	18
Wright-Pat	Dayton OH	VH	25	30	3	6
Wurtsmith	Flint MI	VH	25	30	3	6

Appendix F: System Parameters (Wray, 1983:61-65)

DIRECT GAIN SYSTEMS

System-Numbering Convention

First digit: Mass-area-to-glazing-area ratio (3, 6, or 9)

Second digit: Mass thickness in inches (2, 4, or 6)

Third digit: R-value of night insulation (0, 4, or 9)

Fourth digit: Number of glazings (1, 2, or 3)

System No. (ascending order)	F	G	U_c	α
3201	0.458	22.56	1.10	0.94
3202	0.576	10.32	0.49	0.94
3203	0.661	6.48	0.31	0.94
3241	0.608	9.60	0.61	0.94
3242	0.623	5.04	0.35	0.94
3243	0.669	3.36	0.28	0.94
3291	0.637	8.16	0.53	0.94
3292	0.651	3.60	0.27	0.94
3293	0.685	2.16	0.19	0.94
3401	0.754	24.72	1.10	0.94
3402	0.838	10.56	0.49	0.94
3403	0.886	6.00	0.31	0.94
3441	0.822	10.08	0.61	0.94
3442	0.834	4.80	0.35	0.94
3443	0.875	2.88	0.28	0.94
3491	0.832	8.40	0.53	0.94
3492	0.852	3.31	0.27	0.94
3493	0.882	1.63	0.19	0.94
3601	0.826	24.96	1.10	0.94
3602	0.894	10.32	0.49	0.94
3603	0.943	5.76	0.31	0.94
3641	0.870	9.84	0.61	0.94
3642	0.870	4.32	0.35	0.94
3643	0.910	2.40	0.28	0.94
3691	0.865	7.92	0.53	0.94
3692	0.889	2.83	0.27	0.94
3693	0.916	1.15	0.19	0.94
6201	0.719	24.72	1.10	0.97
6202	0.812	10.56	0.49	0.97
6203	0.867	6.00	0.31	0.97
6241	0.786	9.84	0.61	0.97
6242	0.810	4.80	0.35	0.97
6243	0.857	2.88	0.28	0.97
6291	0.796	8.16	0.53	0.97
6292	0.832	3.36	0.27	0.97
6293	0.866	1.68	0.19	0.97
6401	1.013	26.40	1.10	0.97
6402	1.024	10.32	0.49	0.97

DIRECT GAIN SYSTEMS (cont)

System No. (ascending order)	F	G	U_c	α
6403	1.062	5.52	0.31	0.97
6441	0.964	9.84	0.61	0.97
6442	0.966	4.08	0.35	0.97
6443	1.015	2.16	0.28	0.97
6491	0.967	7.92	0.53	0.97
6492	0.964	2.40	0.27	0.97
6493	1.020	0.96	0.19	0.97
6601	1.089	26.64	1.10	0.97
6602	1.079	10.08	0.49	0.97
6603	1.095	5.04	0.31	0.97
6641	1.013	9.60	0.61	0.97
6642	1.019	3.84	0.35	0.97
6643	1.046	1.68	0.28	0.97
6691	1.005	7.68	0.53	0.97
6692	0.997	1.92	0.27	0.97
6693	1.051	0.48	0.19	0.97
9201	0.906	25.92	1.10	0.98
9202	0.943	10.32	0.49	0.98
9203	0.983	5.52	0.31	0.98
9241	0.896	9.84	0.61	0.98
9242	0.909	4.32	0.35	0.98
9243	0.962	2.40	0.28	0.98
9291	0.889	7.92	0.53	0.98
9292	0.926	2.88	0.27	0.98
9293	0.967	1.20	0.19	0.98
9401	1.191	27.60	1.10	0.98
9402	1.131	10.08	0.49	0.98
9403	1.149	5.04	0.31	0.98
9441	1.050	9.60	0.61	0.98
9442	1.063	3.84	0.35	0.98
9443	1.095	1.68	0.28	0.98
9491	1.041	7.68	0.53	0.98
9492	1.059	2.16	0.27	0.98
9493	1.097	0.48	0.19	0.98
9601	1.268	27.84	1.10	0.98
9602	1.200	10.08	0.49	0.98
9603	1.220	5.04	0.31	0.98
9641	1.113	9.60	0.61	0.98
9642	1.093	3.36	0.35	0.98
9643	1.143	1.44	0.28	0.98
9691	1.088	7.44	0.53	0.98
9692	1.088	1.68	0.27	0.98
9693	1.145	0.24	0.19	0.98

VENTED TROMBE WALLS

System-Numbering Convention

First digit: Mass thickness in 6-in. increments (1, 2, or 3 implies 6 in., 12 in., or 18 in., respectively)

Second digit: ρck product in increments of 15 (1 or 2 implies 15 or 30, respectively)

Third digit: R-value of night insulation (0 or 9)

Fourth digit: Number of glazings (1 or 2)

Note: Not all combinations are allowed. Double-glazed systems with no night insulation and ρck equal to 15 or 30 are available in thickness of 6 in., 12 in., or 18 in. For the 12 in. wall with $\rho ck = 30$, one can also select a single-glazed system with or without R9 night insulation or a double-glazed system with R9 night insulation.

System No. (ascending order)	F	G	U_c	α
1102	0.605	5.28	0.24	0.95
1202	0.629	6.00	0.27	0.95
2102	0.638	4.32	0.19	0.95
2201	0.545	7.92	0.29	0.95
2202	0.741	5.28	0.24	0.95
2291	0.728	4.08	0.20	0.95
2292	0.861	2.16	0.15	0.95
3102	0.569	3.60	0.16	0.95
3202	0.709	4.56	0.21	0.95

UNVENTED TROMBE WALLS

System-Numbering Convention

First digit: Mass thickness in 6-in. increments (1, 2, or 3 implies 6 in., 12 in., or 18 in., respectively)

Second digit: ρck product in increments 15 (1 or 2 implies 15 or 30, respectively)

Third digit: R-value of night insulation (0 or 9)

Fourth digit: Number of glazings (1 or 2)

Note: Not all combinations are allowed. Double-glazed systems with no night insulation and ρck equal to 15 or 30 are available in thickness of 6 in., 12 in., or 18 in. For the 12 in. wall with ρck = 30 one can also select a single-glazed system with or without R9 night insulation or a double-glazed system with R9 night insulation.

System No. (ascending order)	F	G	U_c	α
1102	0.551	5.04	0.24	0.95
1202	0.616	6.00	0.27	0.95
2102	0.496	3.60	0.19	0.95
2201	0.484	7.44	0.29	0.95
2202	0.644	4.80	0.24	0.95
2291	0.611	3.12	0.20	0.95
2292	0.755	1.68	0.15	0.95
3102	0.406	2.88	0.16	0.95
3202	0.570	3.84	0.21	0.95

WATER WALLS

System-Numbering Convention

First digit: Wall thickness (1, 2, or 3 implies 6 in., 9 in., or 12 in., respectively)

Second digit: R-value of night insulation (0 or 9)

Third digit: Number of glazings (1 or 2)

Note: All combinations are not allowed. For 6 in. or 12 in. walls only double glazing without night insulation is allowed. Single or double glazing with or without night insulation are allowed with 9 in. walls.

System No. (ascending order)	F	G	U_c	α
102	0.833	6.48	0.31	0.95
210	0.735	10.80	0.41	0.95
202	0.885	6.24	0.31	0.95
291	0.873	3.84	0.25	0.95
292	0.981	1.92	0.18	0.95
302	0.907	6.00	0.21	0.95

CONCRETE BLOCK WALLS

System-Numbering Convention

First digit: Unfilled or filled (1 implies unfilled blocks and 2 implies filled)

Second digit: Number of glazings (1 or 2)

Note: Concrete blocks are 8-in. thick and no night insulation is used.

System No. (ascending order)	F	G	U_c	α
11	0.454	5.28	0.42	0.95
12	0.500	3.12	0.28	0.95
21	0.575	6.00	0.47	0.95
22	0.630	3.60	0.31	0.95

Appendix G: Weather Parameters (Wray, 1983:67-108)

BIRMINGHAM, ALABAMA — LATITUDE = 33.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	183.47	114.59	78.84	57.70	43.63	33.98	27.48
VT2/DD	156.18	97.55	67.12	49.12	37.14	28.92	23.40
VT3/DD	135.57	84.68	58.26	42.64	32.24	25.11	20.31
ANNUAL DD	314	581	977	1504	2174	3019	4077
PARAMETER A	.658	.680	.641	.589	.567	.567	.590
OFF SOUTH							
VTN/DD B1	-.509	-.509	-.509	-.509	-.509	-.509	-.509
VTN/DD B2	-.095	-.095	-.095	-.095	-.095	-.095	-.095
A PARAM C1	.589	.605	.671	.750	.787	.795	.778
A PARAM C2	.004	.011	.022	.035	.046	.054	.063

MOBILE, ALABAMA — LATITUDE = 30.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	1855.5	536.16	238.87	133.95	83.68	57.20	42.32
VT2/DD	1576.5	455.55	202.96	113.81	71.10	48.60	35.96
VT3/DD	1368.2	395.35	176.13	98.77	61.71	42.18	31.21
ANNUAL DD	31	132	326	642	1130	1795	2658
PARAMETER A	.701	.664	.567	.483	.465	.476	.492
OFF SOUTH							
VTN/DD B1	-.089	-.089	-.089	-.089	-.089	-.089	-.089
VTN/DD B2	-.090	-.090	-.090	-.090	-.090	-.090	-.090
A PARAM C1	-.001	-.086	-.127	-.174	-.202	-.194	-.160
A PARAM C2	.045	.038	.042	.051	.058	.067	.077

MONTGOMERY, ALABAMA — LATITUDE = 32.2

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	370.49	199.27	115.58	74.45	52.85	40.07	31.99
VT2/DD	316.05	169.99	98.32	63.33	44.96	34.09	27.22
VT3/DD	274.47	147.63	85.35	54.98	39.02	29.59	23.63
ANNUAL DD	185	379	695	1155	1774	2572	3546
PARAMETER A	.427	.374	.419	.468	.510	.537	.550
OFF SOUTH							
VTN/DD B1	.663	.663	-.275	-.275	-.275	-.275	-.275
VTN/DD B2	-.103	-.103	-.092	-.092	-.092	-.092	-.092
A PARAM C1	-1.830	-2.206	2.013	1.724	1.499	1.347	1.231
A PARAM C2	.050	.064	.014	.022	.028	.037	.051

PHOENIX, ARIZONA — LATITUDE = 33.0

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	1415.9	558.44	291.36	175.12	118.02	85.26	64.50
VT2/DD	1210.9	477.60	249.18	149.77	100.94	72.92	55.16
VT3/DD	1052.2	415.01	216.52	130.14	87.71	63.36	47.93
ANNUAL DD	43	140	328	634	1090	1713	2503
PARAMETER A	.508	.593	.593	.571	.554	.529	.511
OFF SOUTH							
VTN/DD B1	.287	.287	.287	.287	.287	.287	.287
VTN/DD B2	-.115	-.115	-.115	-.115	-.115	-.115	-.115
A PARAM C1	-.506	-.518	-.490	-.447	-.408	-.391	-.375
A PARAM C2	.012	.023	.039	.054	.070	.088	.107

PRESCOTT, ARIZONA — LATITUDE = 34.4

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	173.09	116.89	85.65	66.45	53.63	44.77	38.32
VT2/DD	148.25	100.11	73.35	56.91	45.93	38.35	32.82
VT3/DD	128.86	87.02	63.76	49.47	39.92	33.33	28.53
ANNUAL DD	784	1304	1975	2801	3783	4937	6261
PARAMETER A	.583	.535	.497	.462	.434	.413	.398
OFF SOUTH							
VTN/DD B1	-.097	-.097	-.097	-.097	-.097	-.097	-.097
VTN/DD B2	-.120	-.120	-.120	-.120	-.120	-.120	-.120
A PARAM C1	-.012	.065	.160	.267	.377	.483	.597
A PARAM C2	.067	.094	.127	.164	.203	.238	.275

TUCSON, ARIZONA — LATITUDE = 32.1

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 1)
VT1/DD	1309.1	592.51	318.15	193.12	127.49	92.09	69.21
VT2/DD	1120.0	506.92	272.19	163.47	107.92	77.95	59.10
VT3/DD	973.38	440.55	236.55	141.71	93.55	67.57	51.35
ANNUAL DD	69	185	416	794	1330	2025	2879
PARAMETER A	.645	.510	.422	.403	.401	.373	.363
OFF SOUTH							
VTN/DD B1	-.061	-.061	-.061	.158	.158	.158	.017
VTN/DD B2	-.118	-.118	-.118	-.083	-.083	-.083	-.111
A PARAM C1	.252	.372	.505	-.387	-.334	-.292	.395
A PARAM C2	.047	.068	.096	-.054	-.033	-.005	.170

WINSLOW, ARIZONA — LATITUDE = 35.0

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	160.31	107.81	79.43	62.17	50.90	43.01	37.23
VT2/DD	137.37	92.39	68.07	53.28	43.62	36.86	31.90
VT3/DD	119.41	80.31	59.17	46.31	37.91	32.04	27.73
ANNUAL DD	913	1476	2180	3029	4014	5147	6429
PARAMETER A	.482	.482	.465	.447	.428	.412	.396
OFF SOUTH							
VTN/DD B1	-.157	-.157	-.157	-.157	-.157	-.157	-.157
VTN/DD B2	-.122	-.122	-.122	-.122	-.122	-.122	-.122
A PARAM C1	.944	.985	1.059	1.137	1.221	1.294	1.383
A PARAM C2	.082	.098	.121	.147	.177	.209	.245

YUMA, ARIZONA — LATITUDE = 32.4

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	2402.3	804.25	365.88	192.42	119.03	82.89
VT2/DD	NA	2054.9	687.96	312.98	164.26	101.61	70.75
VT3/DD	NA	1785.7	597.84	271.98	142.70	88.28	61.47
ANNUAL DD	NA	36	119	308	654	1171	1870
PARAMETER A	NA	.196	.362	.446	.566	.616	.610
OFF SOUTH							
VTN/DD B1	NA	-.091	-.091	-.091	-.108	-.108	-.108
VTN/DD B2	NA	-.117	-.117	-.117	-.110	-.110	-.110
A PARAM C1	NA	.028	.059	.109	.212	.264	.320
A PARAM C2	NA	.059	.042	.046	.030	.046	.064

FORT SMITH, ARKANSAS — LATITUDE = 35.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	148.07	91.48	64.01	48.41	38.60	31.96	27.22
VT2/DD	126.53	78.17	54.70	41.37	32.99	27.31	23.26
VT3/DD	109.92	67.90	47.52	35.93	28.66	23.73	20.21
ANNUAL DD	512	908	1425	2074	2844	3734	4770
PARAMETER A	.598	.606	.596	.578	.563	.553	.552
OFF SOUTH							
VTN/DD B1	-.211	-.211	-.211	-.211	-.211	-.211	-.211
VTN/DD B2	-.110	-.110	-.110	-.110	-.110	-.110	-.110
A PARAM C1	.226	.205	.201	.217	.245	.274	.292
A PARAM C2	.034	.038	.044	.051	.059	.068	.079

LITTLE ROCK, ARKANSAS — LATITUDE = 34.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	191.20	116.00	77.89	56.34	43.42	35.09	29.27
VT2/DD	163.08	98.94	66.43	48.06	37.04	29.93	24.97
VT3/DD	141.62	85.92	57.69	41.73	32.16	25.99	21.68
ANNUAL DD	361	683	1141	1738	2455	3316	4346
PARAMETER A	.643	.596	.551	.520	.501	.496	.507
OFF SOUTH							
VTN/DD B1	-.433	-.433	-.433	-.433	-.433	-.433	-.433
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	-.661	-.721	-.784	-.816	-.818	-.784	-.715
A PARAM C2	.018	.026	.036	.046	.054	.064	.074

ARCATA, CALIFORNIA LATITUDE = 40.6

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	758.96	275.03	122.98	65.81	42.26	30.75	24.16
VT2/DD	647.85	234.76	105.14	56.26	36.13	26.29	20.66
VT3/DD	562.49	203.83	91.31	48.86	31.38	22.83	17.94
ANNUAL DD	71	279	792	1794	3318	5091	6908
PARAMETER A	.673	.674	.632	.667	.658	.589	.529
OFF SOUTH							
VTN/DD B1	.210	.210	.566	.566	.566	.566	.566
VTN/DD B2	-.102	-.102	-.108	-.108	-.108	-.108	-.108
A PARAM C1	.136	-.202	-1.525	-1.682	-2.083	-2.761	-3.377
A PARAM C2	.020	.048	.093	.109	.140	.184	.222

BAKERSFIELD, CALIFORNIA LATITUDE = 35.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	983.14	335.12	158.77	89.93	59.23	43.57	34.26
VT2/DD	840.48	286.49	135.73	76.88	50.64	37.25	29.29
VT3/DD	730.05	248.85	117.89	66.78	43.98	32.35	25.44
ANNUAL DD	55	199	489	974	1661	2528	3576
PARAMETER A	.491	.530	.554	.642	.728	.765	.782
OFF SOUTH							
VTN/DD B1	-.175	-.175	-.175	-.175	-.175	-.175	-.175
VTN/DD B2	-.112	-.112	-.112	-.112	-.112	-.112	-.112
A PARAM C1	-.843	-.762	-.645	-.470	-.345	-.276	-.228
A PARAM C2	.013	.020	.026	.029	.036	.048	.062

CHINA LAKE, CALIFORNIA LATITUDE = 35.4

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	530.96	250.77	146.98	97.65	70.56	54.49	44.33
VT2/DD	455.09	214.94	125.98	83.70	60.48	46.70	37.99
VT3/DD	395.56	186.82	109.50	72.75	52.57	40.59	33.02
ANNUAL DD	168	388	740	1245	1915	2751	3735
PARAMETER A	.415	.562	.622	.639	.632	.605	.573
OFF SOUTH							
VTN/DD B1	.037	.037	.037	.037	.037	.037	.037
VTN/DD B2	-.124	-.124	-.124	-.124	-.124	-.124	-.124
A PARAM C1	.152	.092	.068	.052	.042	.035	.031
A PARAM C2	.025	.024	.031	.044	.062	.083	.106

DAGGETT, CALIFORNIA LATITUDE = 34.5

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	834.26	362.50	201.47	126.42	87.14	64.60	50.81
VT2/DD	713.55	310.51	172.58	108.29	74.64	55.33	43.52
VT3/DD	620.06	269.86	149.99	94.11	64.87	48.09	37.82
ANNUAL DD	101	252	516	950	1585	2405	3393
PARAMETER A	.254	.402	.508	.593	.613	.604	.583
OFF SOUTH							
VTN/DD B1	.078	.418	.418	.418	.418	.418	.418
VTN/DD B2	-.117	-.122	-.122	-.122	-.122	-.122	-.122
A PARAM C1	1.243	-.890	-.762	-.713	-.734	-.767	-.805
A PARAM C2	-.014	.020	.027	.040	.061	.085	.111

EL TORO, CALIFORNIA LATITUDE = 33.4

DUE SOUTH	TR40 (M=12)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M=12)	TR65 (M=12)	TR70 (M= 5)
VT1/DD	NA	2659.9	743.15	312.48	162.32	101.71	66.69
VT2/DD	NA	2272.1	634.80	266.92	138.88	87.03	53.85
VT3/DD	NA	1974.0	551.51	231.90	120.68	75.62	45.54
ANNUAL DD	NA	31	153	482	1149	2196	3558
PARAMETER A	NA	.420	.517	.491	.384	.322	.434
OFF SOUTH							
VTN/DD B1	NA	-.318	-.318	-.318	-.210	-.210	-2.367
VTN/DD B2	NA	-.112	-.112	-.112	-.117	-.117	.124
A PARAM C1	NA	.099	.003	-.292	-1.307	-2.021	2.621
A PARAM C2	NA	-.002	.029	.106	.241	.358	-.479

FRESNO, CALIFORNIA LATITUDE = 37.0

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	325.52	144.54	79.90	50.55	36.34	28.25	23.10
VT2/DD	277.87	123.38	68.21	43.15	31.02	24.11	19.72
VT3/DD	241.26	107.13	59.22	37.47	26.93	20.94	17.12
ANNUAL DD	127	343	741	1356	2171	3172	4343
PARAMETER A	.651	.715	.787	.869	.920	.954	.977
OFF SOUTH							
VTN/DD B1	-.631	-.631	-.631	-.631	-.631	-.631	-.631
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	.117	.127	.170	.219	.265	.302	.339
A PARAM C2	.008	.009	.011	.016	.022	.029	.036

LOS ANGELES, CALIFORNIA LATITUDE = 33.6

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M= 3)	TR70 (M= 4)
VT1/DD	NA	NA	1359.9	449.75	197.14	112.97	74.56
VT2/DD	NA	NA	1163.5	384.81	168.68	94.09	60.50
VT3/DD	NA	NA	1011.0	334.37	146.57	80.99	51.23
ANNUAL DD	NA	NA	45	240	818	1851	3300
PARAMETER A	NA	NA	.741	.631	.416	.361	.355
OFF SOUTH							
VTN/DD B1	NA	NA	-.372	-.372	-.372	-1.178	-1.022
VTN/DD B2	NA	NA	-.117	-.117	-.117	-.036	.055
A PARAM C1	NA	NA	.079	.257	.157	2.365	.177
A PARAM C2	NA	NA	.020	.067	.178	-.115	-.393

MOUNT SHASTA, CALIFORNIA LATITUDE = 41.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	99.02	59.97	42.31	32.65	26.59	22.42	19.38
VT2/DD	84.64	51.26	36.17	27.91	22.73	19.16	16.57
VT3/DD	73.52	44.53	31.41	24.24	19.74	16.65	14.39
ANNUAL DD	656	1299	2170	3216	4434	5809	7314
PARAMETER A	.768	.802	.792	.773	.768	.766	.758
OFF SOUTH							
VTN/DD B1	.382	.382	.382	.382	.382	.382	.382
VTN/DD B2	-.108	-.108	-.108	-.108	-.108	-.108	-.108
A PARAM C1	-.773	-.858	-.971	-1.052	-1.079	-1.086	-1.100
A PARAM C2	.006	.015	.027	.038	.049	.061	.074

OAKLAND, CALIFORNIA LATITUDE = 37.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	642.88	214.95	104.72	63.77	44.97	34.70
VT2/DD	NA	549.00	183.56	89.43	54.46	38.40	29.63
VT3/DD	NA	476.80	159.42	77.67	47.30	33.35	25.73
ANNUAL DD	NA	60	245	741	1734	3215	4918
PARAMETER A	NA	.600	.814	.898	.872	.817	.710
OFF SOUTH							
VTN/DD B1	NA	-.953	-.953	-.953	-.953	-.953	-.953
VTN/DD B2	NA	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	NA	.606	.677	.826	.913	.922	.998
A PARAM C2	NA	-.009	-.004	.017	.051	.093	.142

POINT MUGU, CALIFORNIA LATITUDE = 34.1

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M= 3)	TR60 (M= 3)	TR65 (M= 3)	TR70 (M= 5)
VT1/DD	NA	2548.7	724.70	311.40	151.81	91.52	56.65
VT2/DD	NA	2181.9	620.39	258.97	126.25	76.11	45.70
VT3/DD	NA	1896.1	539.13	222.73	108.58	65.46	38.61
ANNUAL DD	NA	38	177	524	1237	2430	4006
PARAMETER A	NA	.460	.545	.515	.528	.433	.527
OFF SOUTH							
VTN/DD B1	NA	-.071	-.071	-.125	-.125	-.125	-1.520
VTN/DD B2	NA	-.119	-.119	-.028	-.028	-.028	.132
A PARAM C1	NA	-.376	-.287	-.343	-.597	-1.203	1.165
A PARAM C2	NA	.096	.105	-.186	-.101	-.061	-.391

RED BLUFF, CALIFORNIA LATITUDE = 40.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M=12)
VT1/DD	264.10	132.62	77.98	52.73	39.10	30.73	24.80
VT2/DD	225.88	113.43	66.69	45.10	33.44	26.28	21.23
VT3/DD	196.20	98.53	57.93	39.18	29.05	22.83	18.44
ANNUAL DD	137	378	817	1455	2277	3277	4453
PARAMETER A	.714	.767	.762	.740	.737	.749	.790
OFF SOUTH							
VTN/DD B1	-.410	-.410	-.410	-.410	-.410	-.410	-.538
VTN/DD B2	-.112	-.112	-.112	-.112	-.112	-.112	-.116
A PARAM C1	-.046	-.044	-.001	.039	.078	.113	.428
A PARAM C2	-.001	.003	.012	.023	.034	.043	.058

SAN DIEGO, CALIFORNIA LATITUDE = 32.4

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	NA	1939.1	546.14	215.22	112.32	73.74
VT2/DD	NA	NA	1654.1	465.88	183.59	95.81	62.90
VT3/DD	NA	NA	1436.7	404.66	159.47	83.22	54.64
ANNUAL DD	NA	NA	31	159	572	1460	2826
PARAMETER A	NA	NA	.376	.600	.535	.456	.383
OFF SOUTH							
VTN/DD B1	NA	NA	-.198	-.198	-.198	-.198	-.198
VTN/DD B2	NA	NA	-.107	-.107	-.107	-.107	-.107
A PARAM C1	NA	NA	-.027	-.405	-1.062	-1.689	-2.437
A PARAM C2	NA	NA	-.013	.020	.082	.168	.267

SAN FRANCISCO, CALIFORNIA TM LATITUDE = 37.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	565.00	212.21	107.57	66.69	47.03	36.18
VT2/DD	NA	482.59	181.26	91.88	56.96	40.17	30.90
VT3/DD	NA	419.14	157.42	79.80	49.47	34.89	26.84
ANNUAL DD	NA	90	331	982	2175	3703	5395
PARAMETER A	NA	.681	.828	.863	.814	.708	.608
OFF SOUTH							
VTN/DD B1	NA	-.770	-.770	-.770	-.770	-.770	-.770
VTN/DD B2	NA	-.108	-.108	-.108	-.108	-.108	-.108
A PARAM C1	NA	.286	.370	.495	.594	.699	.808
A PARAM C2	NA	-.005	.012	.048	.089	.140	.193

SANTA MARIA, CALIFORNIA LATITUDE = 34.8

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 6)
VT1/DD	818.91	399.74	226.36	134.11	86.37	61.39	46.26
VT2/DD	699.61	341.50	193.39	114.58	73.78	52.44	37.29
VT3/DD	607.71	296.64	167.98	99.52	64.09	45.55	31.57
ANNUAL DD	72	192	467	1113	2253	3700	5350
PARAMETER A	.515	.720	.750	.720	.578	.417	.400
OFF SOUTH							
VTN/DD B1	-.166	-.166	-.166	-.166	-.166	-.166	-1.779
VTN/DD B2	-.111	-.111	-.111	-.111	-.111	-.111	.170
A PARAM C1	-.235	-.117	-.152	-.342	-.840	-1.596	1.077
A PARAM C2	.002	.017	.044	.104	.199	.329	-.579

SUNNYVALE, CALIFORNIA LATITUDE = 37.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	NA	613.36	269.61	130.65	75.01	51.18	38.68
VT2/DD	NA	524.83	230.70	111.79	64.18	43.79	33.09
VT3/DD	NA	455.93	200.41	97.11	55.76	38.04	28.75
ANNUAL DD	NA	97	323	831	1730	3034	4612
PARAMETER A	NA	.871	.717	.646	.696	.716	.664
OFF SOUTH							
VTN/DD B1	NA	-.445	-.445	-.445	-.445	-.445	-.445
VTN/DD B2	NA	-.115	-.115	-.115	-.115	-.115	-.115
A PARAM C1	NA	.385	.631	.705	.555	.410	.308
A PARAM C2	NA	.015	.041	.067	.081	.108	.133

COLORADO SPRINGS, COLORADO LATITUDE = 38.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 3)	TR70 (M= 3)
VT1/DD	122.79	90.69	70.63	56.65	46.96	40.29	34.38
VT2/DD	105.17	77.68	60.04	48.16	39.91	33.64	28.70
VT3/DD	91.41	67.51	52.08	41.77	34.62	28.96	24.71
ANNUAL DD	1414	2097	2932	3934	5097	6440	7936
PARAMETER A	.336	.310	.308	.314	.314	.328	.342
OFF SOUTH							
VTN/DD B1	-.322	-.322	-.153	-.153	-.153	-.233	-.233
VTN/DD B2	-.117	-.117	-.092	-.092	-.092	-.025	-.025
A PARAM C1	1.215	1.462	.464	.624	.798	1.205	1.356
A PARAM C2	.142	.172	.031	.057	.086	-.219	-.179

DENVER, COLORADO LATITUDE = 39.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	103.58	78.15	61.70	49.69	41.32	35.26	30.74
VT2/DD	88.76	66.97	52.45	42.24	35.12	29.97	26.14
VT3/DD	77.15	58.21	45.49	36.64	30.46	26.00	22.67
ANNUAL DD	1510	2209	3059	4059	5223	6542	8004
PARAMETER A	.428	.416	.418	.430	.437	.438	.429
OFF SOUTH							
VTN/DD B1	-.432	-.432	-.197	-.197	-.197	-.197	-.197
VTN/DD B2	-.119	-.119	-.091	-.091	-.091	-.091	-.091
A PARAM C1	1.202	1.436	.478	.620	.762	.904	1.064
A PARAM C2	.075	.091	-.021	-.002	.020	.044	.071

EAGLE, COLORADO LATITUDE = 39.4

DUE SOUTH	TR40 (M=12)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	53.50	43.15	35.95	30.81	26.96	23.96	21.57
VT2/DD	45.91	36.93	30.77	26.37	23.07	20.51	18.46
VT3/DD	39.91	32.08	26.73	22.91	20.05	17.82	16.04
ANNUAL DD	2666	3622	4729	5976	7352	8839	10421
PARAMETER A	.568	.585	.597	.601	.595	.577	.550
OFF SOUTH							
VTN/DD B1	.236	.466	.466	.466	.466	.466	.466
VTN/DD B2	-.125	-.113	-.113	-.113	-.113	-.113	-.113
A PARAM C1	.131	-.535	-.498	-.466	-.438	-.414	-.393
A PARAM C2	.075	.046	.060	.076	.094	.117	.144

GRAND JUNCTION, COLORADO LATITUDE = 39.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	69.29	52.95	42.80	35.91	30.93	27.16	24.22
VT2/DD	59.30	45.31	36.62	30.73	26.47	23.24	20.72
VT3/DD	51.52	39.37	31.82	26.70	23.00	20.20	18.01
ANNUAL DD	1397	2076	2890	3820	4870	6040	7347
PARAMETER A	.702	.693	.677	.657	.638	.624	.614
OFF SOUTH							
VTN/DD B1	.019	.019	.019	.019	.019	.019	.019
VTN/DD B2	-.113	-.113	-.113	-.113	-.113	-.113	-.113
A PARAM C1	.296	.270	.255	.245	.238	.235	.236
A PARAM C2	.013	.022	.033	.045	.057	.071	.084

PUEBLO, COLORADO LATITUDE = 38.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	88.66	68.92	55.74	46.44	39.65	34.46	30.46
VT2/DD	75.91	59.01	47.72	39.77	33.95	29.51	26.08
VT3/DD	65.97	51.28	41.47	34.56	29.50	25.64	22.66
ANNUAL DD	1449	2035	2755	3614	4613	5774	7107
PARAMETER A	.584	.578	.565	.555	.540	.528	.511
OFF SOUTH							
VTN/DD B1	-.311	-.311	-.311	-.311	-.311	-.311	-.311
VTN/DD B2	-.116	-.116	-.116	-.116	-.116	-.116	-.116
A PARAM C1	.974	1.036	1.117	1.197	1.293	1.386	1.500
A PARAM C2	.062	.068	.077	.089	.104	.122	.144

HARTFORD, CONNECTICUT LATITUDE = 41.8

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	34.62	25.30	19.66	15.98	13.43	11.57	10.16
VT2/DD	29.59	21.62	16.80	13.66	11.48	9.89	8.68
VT3/DD	25.70	18.77	14.59	11.86	9.97	8.59	7.54
ANNUAL DD	1549	2262	3115	4106	5232	6506	7927
PARAMETER A	.635	.692	.752	.806	.850	.887	.919
OFF SOUTH							
VTN/DD B1	.024	.024	.024	.024	.024	.024	.024
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	-.494	-.402	-.326	-.267	-.224	-.190	-.164
A PARAM C2	.032	.034	.035	.037	.039	.042	.045

WILMINGTON, DELAWARE LATITUDE = 39.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	62.23	44.34	33.95	27.40	22.93	19.72	17.29
VT2/DD	53.17	37.89	29.01	23.41	19.60	16.85	14.78
VT3/DD	46.18	32.91	25.19	20.34	17.02	14.64	12.84
ANNUAL DD	902	1493	2239	3105	4094	5211	6493
PARAMETER A	.626	.630	.615	.600	.593	.591	.597
OFF SOUTH							
VTN/DD B1	-.421	-.421	-.421	-.421	-.421	-.421	-.421
VTN/DD B2	-.108	-.108	-.108	-.108	-.108	-.108	-.108
A PARAM C1	.861	.945	1.034	1.099	1.131	1.143	1.125
A PARAM C2	.025	.033	.044	.054	.065	.075	.085

WASHINGTON DC LATITUDE = 38.9

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M=12)
VT1/DD	68.81	49.61	37.81	30.39	25.30	21.61	18.79
VT2/DD	58.80	42.39	32.31	25.96	21.62	18.47	16.08
VT3/DD	51.07	36.82	28.06	22.55	18.77	16.04	13.97
ANNUAL DD	894	1430	2113	2930	3887	5004	6284
PARAMETER A	.594	.557	.538	.536	.541	.554	.569
OFF SOUTH							
VTN/DD B1	.621	.621	.621	.621	.621	.621	-.192
VTN/DD B2	-.108	-.108	-.108	-.108	-.108	-.108	-.112
A PARAM C1	-1.224	-1.462	-1.602	-1.658	-1.666	-1.641	.923
A PARAM C2	.036	.045	.054	.063	.072	.080	.104

APALACHICOLA, FLORIDA LATITUDE = 30.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	1417.8	578.73	286.23	161.08	100.04	66.88	48.11
VT2/DD	1205.3	491.99	243.33	136.94	85.05	56.85	40.90
VT3/DD	1046.1	427.02	211.20	118.85	73.81	49.35	35.49
ANNUAL DD	37	112	265	524	932	1534	2342
PARAMETER A	.719	.675	.578	.521	.516	.532	.547
OFF SOUTH							
VTN/DD B1	-.365	-.365	-.365	-.365	-.365	-.365	-.365
VTN/DD B2	-.092	-.092	-.092	-.092	-.092	-.092	-.092
A PARAM C1	.242	.294	.394	.467	.478	.467	.456
A PARAM C2	.011	.010	.014	.019	.027	.035	.048

DAYTONA BEACH, FLORIDA LATITUDE = 29.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	1488.1	620.18	323.32	194.58	124.15	83.75	59.75
VT2/DD	1265.5	527.40	274.95	165.47	105.58	71.22	50.81
VT3/DD	1098.6	457.87	238.70	143.66	91.66	61.83	44.11
ANNUAL DD	26	65	151	298	570	1009	1652
PARAMETER A	.302	.461	.623	.726	.772	.744	.689
OFF SOUTH							
VTN/DD B1	-.402	-.402	-.402	-.402	-.402	-.402	-.402
VTN/DD B2	-.096	-.096	-.096	-.096	-.096	-.096	-.096
A PARAM C1	.352	.211	.220	.264	.372	.532	.722
A PARAM C2	.046	.026	.022	.024	.029	.040	.056

JACKSONVILLE, FLORIDA LATITUDE = 30.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	640.73	324.39	196.57	126.68	84.85	60.29	45.41
VT2/DD	545.04	275.94	167.21	107.76	72.18	51.28	38.63
VT3/DD	473.16	239.55	145.16	93.55	62.66	44.52	33.54
ANNUAL DD	85	187	354	615	1004	1561	2321
PARAMETER A	.696	.633	.580	.571	.565	.558	.555
OFF SOUTH							
VTN/DD B1	-.511	-.511	-.511	-.511	-.511	-.511	-.511
VTN/DD B2	-.095	-.095	-.095	-.095	-.095	-.095	-.095
A PARAM C1	.297	.329	.384	.422	.445	.484	.543
A PARAM C2	.001	.007	.013	.020	.028	.037	.049

MIAMI, FLORIDA LATITUDE = 25.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	NA	NA	NA	1056.0	503.81	282.40	179.75
VT2/DD	NA	NA	NA	897.18	428.03	239.92	152.72
VT3/DD	NA	NA	NA	778.88	371.59	208.29	132.58
ANNUAL DD	NA	NA	NA	59	133	264	507
PARAMETER A	NA	NA	NA	.365	.361	.454	.534
OFF SOUTH							
VTN/DD B1	NA	NA	NA	.022	.022	.022	.022
VTN/DD B2	NA	NA	NA	-.091	-.091	-.091	-.091
A PARAM C1	NA	NA	NA	1.057	1.048	.813	.770
A PARAM C2	NA	NA	NA	.041	.045	.040	.052

ORLANDO, FLORIDA LATITUDE = 28.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	1799.4	668.95	329.72	183.50	114.01	77.22
VT2/DD	NA	1529.3	568.56	280.24	155.96	96.90	65.63
VT3/DD	NA	1327.6	493.57	243.28	135.39	84.12	56.98
ANNUAL DD	NA	27	80	193	413	796	1389
PARAMETER A	NA	.327	.532	.564	.601	.586	.577
OFF SOUTH							
VTN/DD B1	NA	-.115	-.115	-.115	-.115	-.115	-.115
VTN/DD B2	NA	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	NA	-.553	-.305	-.273	-.216	-.155	-.082
A PARAM C2	NA	-.015	-.003	.006	.016	.033	.056

TALLAHASSEE, FLORIDA LATITUDE = 30.2

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	465.39	268.10	168.25	109.37	75.46	55.02	41.97
VT2/DD	395.55	228.38	143.00	92.96	64.13	46.77	35.67
VT3/DD	343.31	198.29	124.12	80.68	55.66	40.59	30.96
ANNUAL DD	143	295	523	855	1323	1958	2793
PARAMETER A	.489	.504	.491	.494	.501	.501	.508
OFF SOUTH							
VTN/DD B1	-.186	-.271	-.186	-.186	-.186	-.186	-.186
VTN/DD B2	-.092	-.100	-.092	-.092	-.092	-.092	-.092
A PARAM C1	-.057	.327	.058	.092	.112	.137	.178
A PARAM C2	-.002	.045	.028	.034	.040	.048	.061

TAMPA, FLORIDA LATITUDE = 27.6

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	NA	1685.2	741.22	396.04	220.55	122.89	78.09
VT2/DD	NA	1432.6	630.15	336.69	185.26	103.23	65.59
VT3/DD	NA	1243.9	547.14	292.34	160.23	89.28	56.73
ANNUAL DD	NA	36	101	232	474	874	1477
PARAMETER A	NA	.380	.374	.369	.410	.522	.560
OFF SOUTH							
VTN/DD B1	NA	.074	.074	.074	.488	.488	.488
VTN/DD B2	NA	-.096	-.096	-.096	-.057	-.057	-.057
A PARAM C1	NA	.126	.094	.085	-1.463	-1.164	-1.107
A PARAM C2	NA	.031	.035	.048	-.099	-.061	-.039

WEST PALM BEACH, FLORIDA — LATITUDE = 26.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	NA	NA	1178.1	519.19	269.83	150.23
VT2/DD	NA	NA	NA	999.57	440.49	228.93	127.46
VT3/DD	NA	NA	NA	867.51	382.29	198.68	110.62
ANNUAL DD	NA	NA	NA	44	123	281	600
PARAMETER A	NA	NA	NA	.317	.681	.705	.644
OFF SOUTH							
VTN/DD B1	NA	NA	NA	.270	.270	.270	.270
VTN/DD B2	NA	NA	NA	-.087	-.087	-.087	-.087
A PARAM C1	NA	NA	NA	.961	.418	.369	.348
A PARAM C2	NA	NA	NA	.056	.026	.033	.050

ATLANTA, GEORGIA — LATITUDE = 33.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	186.80	107.76	69.42	48.63	36.66	29.20	24.25
VT2/DD	159.01	91.73	59.09	41.39	31.21	24.86	20.64
VT3/DD	138.03	79.63	51.30	35.93	27.09	21.58	17.92
ANNUAL DD	332	639	1079	1657	2392	3310	4417
PARAMETER A	.663	.619	.587	.593	.614	.639	.661
OFF SOUTH							
VTN/DD B1	.321	.321	.321	.321	.321	.321	.321
VTN/DD B2	-.094	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	-.569	-.702	-.832	-.885	-.893	-.886	-.871
A PARAM C2	.007	.014	.024	.029	.033	.039	.048

AUGUSTA, GEORGIA — LATITUDE = 33.2

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	258.19	153.24	96.57	65.46	47.62	36.50	29.16
VT2/DD	218.34	129.59	82.16	55.69	40.51	31.06	24.81
VT3/DD	189.21	112.30	71.31	48.34	35.16	26.95	21.53
ANNUAL DD	314	576	952	1458	2115	2938	3957
PARAMETER A	.537	.494	.519	.562	.597	.620	.644
OFF SOUTH							
VTN/DD B1	-.302	-.302	-.056	-.056	-.056	-.056	-.056
VTN/DD B2	-.075	-.075	-.092	-.092	-.092	-.092	-.092
A PARAM C1	.732	.855	.069	.085	.092	.094	.092
A PARAM C2	-.037	-.039	.025	.027	.030	.036	.043

MACON, GEORGIA — LATITUDE = 32.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	267.47	145.68	90.57	62.10	45.32	34.86	28.05
VT2/DD	227.65	123.99	77.09	52.85	38.57	29.67	23.87
VT3/DD	197.62	107.64	66.92	45.88	33.48	25.76	20.72
ANNUAL DD	208	430	775	1244	1859	2643	3624
PARAMETER A	.716	.744	.731	.733	.755	.768	.770
OFF SOUTH							
VTN/DD B1	.111	.111	.111	.111	.111	.111	.111
VTN/DD B2	-.095	-.095	-.095	-.095	-.095	-.095	-.095
A PARAM C1	-.354	-.374	-.413	-.435	-.434	-.435	-.439
A PARAM C2	.008	.008	.012	.018	.023	.030	.039

SAVANNAH, GEORGIA — LATITUDE = 32.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	483.93	239.91	144.08	93.18	64.28	47.43	36.62
VT2/DD	412.16	204.33	122.71	79.36	54.75	40.39	31.19
VT3/DD	357.86	177.41	106.55	68.91	47.54	35.07	27.08
ANNUAL DD	155	328	599	995	1530	2227	3129
PARAMETER A	.624	.597	.556	.536	.546	.559	.581
OFF SOUTH							
VTN/DD B1	.421	.421	.421	.421	.421	.421	.421
VTN/DD B2	-.100	-.100	-.100	-.100	-.100	-.100	-.100
A PARAM C1	-.806	-.922	-1.021	-1.051	-1.010	-.964	-.896
A PARAM C2	.014	.024	.030	.036	.040	.047	.057

BOISE, IDAHO LATITUDE = 43.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	70.75	46.46	34.08	26.88	22.18	18.89	16.44
VT2/DD	60.58	39.83	29.22	23.04	19.02	16.19	14.09
VT3/DD	52.63	34.61	25.39	20.02	16.52	14.07	12.25
ANNUAL DD	973	1651	2494	3503	4667	5981	7429
PARAMETER A	.719	.754	.783	.809	.831	.853	.871
OFF SOUTH							
VTN/DD B1	-.438	.468	.468	.468	.468	.468	.468
VTN/DD B2	-.115	-.118	-.118	-.118	-.118	-.118	-.118
A PARAM C1	1.255	-.862	-.809	-.765	-.734	-.711	-.695
A PARAM C2	.014	.029	.035	.042	.048	.055	.062

LEWISTON, IDAHO LATITUDE = 46.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	45.07	31.12	22.12	16.82	13.57	11.37	9.78
VT2/DD	38.47	26.57	18.93	14.39	11.61	9.73	8.37
VT3/DD	33.40	23.07	16.45	12.50	10.09	8.45	7.27
ANNUAL DD	774	1368	2175	3169	4353	5701	7186
PARAMETER A	.745	.772	.812	.871	.929	.981	1.022
OFF SOUTH							
VTN/DD B1	.999	.999	.166	.166	.166	.166	.166
VTN/DD B2	-.100	-.100	-.111	-.111	-.111	-.111	-.111
A PARAM C1	-.913	-1.032	.561	.468	.400	.351	.315
A PARAM C2	.001	.007	.034	.036	.037	.038	.040

POCATELLO, IDAHO LATITUDE = 42.6

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	45.44	33.91	26.95	22.36	19.10	16.67	14.79
VT2/DD	38.94	29.05	23.09	19.16	16.36	14.28	12.67
VT3/DD	33.83	25.25	20.07	16.65	14.22	12.41	11.01
ANNUAL DD	1740	2587	3583	4711	5969	7352	8847
PARAMETER A	.727	.806	.849	.875	.894	.909	.918
OFF SOUTH							
VTN/DD B1	.134	.134	.134	.134	.134	.134	.134
VTN/DD B2	-.116	-.116	-.116	-.116	-.116	-.116	-.116
A PARAM C1	-.593	-.592	-.581	-.567	-.548	-.526	-.508
A PARAM C2	.024	.031	.038	.044	.051	.058	.064

CHICAGO, ILLINIOS LATITUDE = 41.8

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	39.95	29.06	22.65	18.51	15.62	13.49	11.86
VT2/DD	34.19	24.87	19.38	15.84	13.37	11.54	10.15
VT3/DD	29.70	21.60	16.84	13.76	11.61	10.03	8.82
ANNUAL DD	1581	2284	3100	4026	5076	6272	7622
PARAMETER A	.546	.618	.677	.724	.768	.809	.848
OFF SOUTH							
VTN/DD B1	-.088	-.088	-.088	-.088	-.088	-.088	-.088
VTN/DD B2	-.111	-.111	-.111	-.111	-.111	-.111	-.111
A PARAM C1	.870	.784	.721	.676	.642	.618	.602
A PARAM C2	.048	.047	.047	.049	.051	.053	.055

MOLINE, ILLINIOS LATITUDE = 41.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	34.65	27.60	22.79	19.34	16.79	14.84	13.29
VT2/DD	29.63	23.60	19.48	16.54	14.36	12.69	11.36
VT3/DD	25.73	20.50	16.92	14.36	12.47	11.02	9.87
ANNUAL DD	1722	2411	3208	4126	5182	6381	7735
PARAMETER A	.733	.724	.729	.741	.759	.775	.791
OFF SOUTH							
VTN/DD B1	.115	.115	.115	.115	.115	.115	.115
VTN/DD B2	-.108	-.108	-.108	-.108	-.108	-.108	-.108
A PARAM C1	-.143	-.072	-.008	.057	.120	.180	.229
PARAM C2	.017	.022	.027	.031	.036	.043	.049

SPRINGFIELD, ILLINIOS LATITUDE = 39.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	49.80	35.75	27.40	22.03	18.40	15.79	13.84
VT2/DD	42.58	30.56	23.43	18.83	15.73	13.50	11.83
VT3/DD	36.98	26.55	20.35	16.36	13.66	11.73	10.27
ANNUAL DD	1321	1917	2635	3487	4479	5605	6876
PARAMETER A	.524	.615	.684	.738	.776	.804	.829
OFF SOUTH							
VTN/DD B1	-.300	-.300	-.300	-.300	-.300	-.300	-.300
VTN/DD B2	-.108	-.108	-.108	-.108	-.108	-.108	-.108
A PARAM C1	.619	.486	.409	.369	.352	.347	.344
A PARAM C2	.029	.029	.030	.032	.036	.041	.046

EVANSVILLE, INDIANA LATITUDE = 38.0

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	69.86	46.16	33.82	26.41	21.53	18.10	15.55
VT2/DD	59.67	39.42	28.88	22.56	18.39	15.46	13.28
VT3/DD	51.81	34.23	25.08	19.59	15.97	13.42	11.53
ANNUAL DD	910	1453	2111	2885	3784	4845	6073
PARAMETER A	.424	.504	.551	.582	.617	.662	.707
OFF SOUTH							
VTN/DD B1	-.220	-.220	-.220	-.220	-.220	-.220	-.220
VTN/DD B2	-.104	-.104	-.104	-.104	-.104	-.104	-.104
A PARAM C1	1.857	1.485	1.316	1.211	1.114	1.012	.926
A PARAM C2	.047	.045	.047	.050	.051	.053	.055

FORT WAYNE, INDIANA LATITUDE = 41.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	28.15	22.22	18.30	15.55	12.99	11.06	9.61
VT2/DD	24.03	18.96	15.62	13.27	11.08	9.43	8.20
VT3/DD	20.86	16.46	13.56	11.52	9.62	8.19	7.12
ANNUAL DD	1649	2341	3141	4061	5121	6340	7731
PARAMETER A	.678	.643	.637	.648	.719	.789	.853
OFF SOUTH							
VTN/DD B1	.193	.193	.193	.193	.688	.688	.688
VTN/DD B2	-.101	-.101	-.101	-.101	-.097	-.097	-.097
A PARAM C1	-.046	-.082	-.101	-.105	-1.220	-1.080	-.967
A PARAM C2	.036	.044	.048	.051	.038	.038	.039

INDIANAPOLIS, INDIANA LATITUDE = 39.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	34.33	26.83	20.71	16.58	13.80	11.82	10.34
VT2/DD	29.30	22.90	17.67	14.14	11.78	10.09	8.83
VT3/DD	25.44	19.88	15.34	12.28	10.22	8.76	7.66
ANNUAL DD	1392	2032	2807	3703	4713	5867	7185
PARAMETER A	.595	.593	.664	.732	.784	.831	.878
OFF SOUTH							
VTN/DD B1	.527	.527	.731	.731	.731	.731	.731
VTN/DD B2	-.102	-.102	-.101	-.101	-.101	-.101	-.101
A PARAM C1	-.134	-.244	-.806	-.768	-.747	-.728	-.706
A PARAM C2	.035	.041	.037	.037	.038	.039	.041

SOUTH BEND, INDIANA LATITUDE = 41.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M=12)	TR70 (M=12)
VT1/DD	28.04	21.48	17.30	14.48	12.44	10.84	9.49
VT2/DD	23.93	18.33	14.76	12.35	10.62	9.25	8.10
VT3/DD	20.77	15.91	12.82	10.73	9.22	8.03	7.03
ANNUAL DD	1564	2279	3125	4098	5206	6464	7884
PARAMETER A	.657	.683	.711	.741	.774	.816	.871
OFF SOUTH							
VTN/DD B1	-.462	-.462	-.462	-.462	-.462	-.228	-.228
VTN/DD B2	-.101	-.101	-.101	-.101	-.101	-.099	-.099
A PARAM C1	.951	.900	.853	.810	.771	.277	.266
A PARAM C2	.032	.034	.037	.039	.041	.039	.040

BURLINGTON, IOWA LATITUDE = 40.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M=12)
VT1/DD	40.89	32.95	27.41	23.43	20.45	18.14	16.06
VT2/DD	34.99	28.19	23.45	20.05	17.50	15.52	13.76
VT3/DD	30.40	24.49	20.38	17.42	15.20	13.49	11.95
ANNUAL DD	1635	2326	3129	4035	5061	6232	7563
PARAMETER A	.677	.648	.625	.616	.621	.628	.655
OFF SOUTH							
VTN/DD B1	-.434	-.434	-.434	-.434	-.434	-.434	-.198
VTN/DD B2	-.113	-.113	-.113	-.113	-.113	-.113	-.116
A PARAM C1	.393	.438	.473	.499	.518	.541	-.097
A PARAM C2	.024	.031	.039	.046	.053	.061	.076

DES MOINES, IOWA LATITUDE = 41.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	35.18	28.85	24.39	21.12	18.62	16.65	15.06
VT2/DD	30.11	24.69	20.87	18.07	15.93	14.25	12.89
VT3/DD	26.16	21.45	18.13	15.70	13.[illegible]4	12.38	11.20
ANNUAL DD	1909	2619	3444	4364	5433	6678	8067
PARAMETER A	.678	.665	.655	.654	.660	.673	.687
OFF SOUTH							
VTN/DD B1	.331	.331	.331	.331	.331	.331	.331
VTN/DD B2	-.113	-.113	-.113	-.113	-.113	-.113	-.113
A PARAM C1	-.369	-.431	-.478	-.501	-.505	-.493	-.476
A PARAM C2	.027	.033	.039	.045	.051	.058	.066

MASON CITY, IOWA LATITUDE = 43.1

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	30.12	24.20	20.22	17.36	15.21	13.53	12.19
VT2/DD	25.82	20.75	17.33	14.88	13.04	11.60	10.45
VT3/DD	22.44	18.03	15.06	12.93	11.33	10.08	9.08
ANNUAL DD	2652	3492	4428	5473	6635	7930	9372
PARAMETER A	.603	.659	.696	.732	.764	.796	.826
OFF SOUTH							
VTN/DD B1	-.894	-.894	-.894	-.894	-.894	-.894	-.894
VTN/DD B2	-.118	-.118	-.118	-.118	-.118	-.118	-.118
A PARAM C1	2.432	2.237	2.127	2.023	1.932	1.848	1.773
A PARAM C2	.045	.046	.048	.051	.054	.056	.060

SIOUX CITY, IOWA LATITUDE = 42.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)
VT1/DD	36.53	30.17	25.67	22.33	19.69	17.25	15.34
VT2/DD	31.29	25.85	21.98	19.13	16.87	14.78	13.14
VT3/DD	27.19	22.46	19.10	16.62	14.66	12.84	11.42
ANNUAL DD	2217	2947	3786	4736	5800	6992	8333
PARAMETER A	.508	.514	.519	.526	.540	.586	.629
OFF SOUTH							
VTN/DD B1	.476	.476	.476	.476	.040	.040	.040
VTN/DD B2	-.116	-.116	-.116	-.116	-.117	-.117	-.117
A PARAM C1	-.916	-.969	-1.036	-1.091	.379	.289	.214
A PARAM C2	.042	.051	.058	.065	.072	.074	.077

DODGE CITY, KANSAS LATITUDE = 37.8

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	81.97	61.62	48.81	40.07	33.88	29.34	25.87
VT2/DD	70.12	52.71	41.75	34.28	28.98	25.09	22.13
VT3/DD	60.92	45.80	36.27	29.78	25.18	21.80	19.23
ANNUAL DD	1254	1860	2580	3419	4392	5506	6775
PARAMETER A	.611	.572	.541	.522	.514	.516	.521
OFF SOUTH							
VTN/DD B1	-.881	-.881	-.881	-.881	-.881	-.881	-.881
VTN/DD B2	-.113	-.113	-.113	-.113	-.113	-.113	-.113
A PARAM C1	1.663	1.935	2.166	2.338	2.426	2.440	2.421
A PARAM C2	.036	.044	.055	.066	.077	.088	.101

GOODLAND, KANSAS LATITUDE = 39.2

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	89.92	65.90	51.24	41.81	35.31	30.56	26.93
VT2/DD	77.04	56.56	43.98	35.88	30.30	26.22	23.11
VT3/DD	66.96	49.17	38.23	31.20	26.34	22.80	20.10
ANNUAL DD	1546	2267	3123	4115	5235	6499	7915
PARAMETER A	.413	.422	.439	.443	.440	.435	.430
OFF SOUTH							
VTN/DD B1	-.575	-.266	-.266	-.266	-.266	-.266	-.266
VTN/DD B2	-.119	-.125	-.125	-.125	-.125	-.125	-.125
A PARAM C1	1.642	.315	.402	.479	.539	.577	.586
A PARAM C2	.080	.124	.133	.148	.168	.189	.212

TOPEKA, KANSAS LATITUDE = 39.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	62.38	48.12	37.97	30.60	25.51	21.86	19.13
VT2/DD	53.36	41.16	32.51	26.20	21.84	18.72	16.38
VT3/DD	46.36	35.76	28.24	22.77	18.98	16.26	14.23
ANNUAL DD	1386	1967	2665	3477	4405	5458	6673
PARAMETER A	.514	.485	.501	.547	.589	.625	.655
OFF SOUTH							
VTN/DD B1	.205	.205	-.234	-.234	-.234	-.234	-.234
VTN/DD B2	-.112	-.112	-.114	-.114	-.114	-.114	-.114
A PARAM C1	-1.096	-1.227	.431	.377	.344	.331	.331
A PARAM C2	.040	.050	.064	.064	.065	.068	.074

LEXINGTON, KENTUCKY LATITUDE = 38.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M=12)
VT1/DD	55.14	40.86	31.61	25.47	21.18	18.06	15.28
VT2/DD	47.04	34.85	26.96	21.72	18.07	15.41	13.04
VT3/DD	40.84	30.26	23.41	18.86	15.68	13.38	11.32
ANNUAL DD	954	1454	2089	2862	3781	4862	6109
PARAMETER A	.365	.586	.595	.600	.610	.628	.687
OFF SOUTH							
VTN/DD B1	-.335	-.335	-.335	-.335	-.335	-.335	-.102
VTN/DD B2	-.100	-.100	-.100	-.100	-.100	-.100	-.101
A PARAM C1	.582	.577	.568	.563	.551	.534	-.085
A PARAM C2	.029	.033	.038	.043	.049	.054	.058

LOUISVILLE, KENTUCKY LATITUDE = 38.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	61.55	44.94	34.34	27.44	22.69	19.22	16.66
VT2/DD	52.52	38.26	29.30	23.41	19.36	16.40	14.21
VT3/DD	45.60	33.22	25.44	20.32	16.81	14.24	12.34
ANNUAL DD	871	1394	2044	2814	3716	4756	5966
PARAMETER A	.664	.636	.624	.621	.628	.639	.654
OFF SOUTH							
VTN/DD B1	-.225	-.225	-.225	-.225	-.225	-.225	-.225
VTN/DD B2	-.101	-.101	-.101	-.101	-.101	-.101	-.101
A PARAM C1	.425	.448	.440	.429	.418	.409	.401
A PARAM C2	.024	.031	.037	.042	.047	.052	.058

BATON ROUGE, LOUISIANA LATITUDE = 30.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	634.57	381.07	203.60	115.23	74.88	53.01	39.82
VT2/DD	541.10	324.94	173.05	97.94	63.64	45.05	33.84
VT3/DD	469.93	282.20	150.20	85.01	55.23	39.11	29.37
ANNUAL DD	72	167	359	690	1169	1813	2643
PARAMETER A	.496	.474	.480	.491	.498	.505	.517
OFF SOUTH							
VTN/DD B1	-.924	-.924	-.049	-.049	-.049	-.049	-.049
VTN/DD B2	-.104	-.104	-.091	-.091	-.091	-.091	-.091
A PARAM C1	1.234	1.922	-1.006	-.820	-.713	-.606	-.485
A PARAM C2	.022	.047	.012	.022	.029	.039	.052

LAKE CHARLES, LOUISIANA — LATITUDE = 30.1

DUE SOUTH	TR40 (M=12)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	852.00	357.05	170.18	97.94	64.62	46.78	35.41
VT2/DD	725.66	303.29	144.56	83.19	54.89	39.74	30.08
VT3/DD	630.05	263.20	125.45	72.20	47.63	34.48	26.10
ANNUAL DD	64	155	329	629	1088	1700	2497
PARAMETER A	.407	.535	.607	.661	.652	.646	.650
OFF SOUTH							
VTN/DD B1	-1.134	-.063	-.063	-.063	-.063	-.063	-.063
VTN/DD B2	-.098	-.088	-.088	-.088	-.088	-.088	-.088
A PARAM C1	3.123	-.827	-.646	-.525	-.458	-.377	-.291
A PARAM C2	.051	.007	.009	.013	.022	.031	.041

NEW ORLEANS, LOUISIANA — LATITUDE = 29.6

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	958.43	436.79	228.05	136.85	91.07	63.59	46.56
VT2/DD	814.85	371.36	193.89	116.35	77.43	54.06	39.58
VT3/DD	707.33	322.35	168.30	101.00	67.21	46.93	34.36
ANNUAL DD	45	124	280	544	940	1526	2323
PARAMETER A	.518	.606	.628	.594	.565	.559	.563
OFF SOUTH							
VTN/DD B1	-.662	-.662	-.662	-.662	-.662	-.662	-.662
VTN/DD B2	-.093	-.093	-.093	-.093	-.093	-.093	-.093
A PARAM C1	-.045	.046	.165	.304	.447	.596	.725
A PARAM C2	-.009	-.002	.007	.018	.029	.042	.057

SHREVEPORT, LOUISIANA — LATITUDE = 32.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	552.54	259.42	142.71	86.56	59.98	44.91	35.30
VT2/DD	471.46	221.35	121.77	73.66	51.05	38.22	30.04
VT3/DD	409.46	192.24	105.76	63.95	44.31	33.18	26.08
ANNUAL DD	111	293	627	1104	1709	2466	3393
PARAMETER A	.580	.504	.448	.471	.478	.495	.516
OFF SOUTH							
VTN/DD B1	-.082	-.082	-.082	-.492	-.492	-.492	-.492
VTN/DD B2	-.104	-.104	-.104	-.094	-.094	-.094	-.094
A PARAM C1	-.546	-.702	-.829	.736	.729	.703	.669
A PARAM C2	.024	.045	.068	.036	.042	.050	.060

BANGOR, MAINE — LATITUDE = 44.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	33.35	26.61	22.12	18.83	16.20	14.21	12.66
VT2/DD	28.58	22.80	18.95	16.14	13.89	12.18	10.85
VT3/DD	24.83	19.81	16.47	14.03	12.07	10.59	9.43
ANNUAL DD	2370	3232	4229	5381	6692	8167	9780
PARAMETER A	.394	.436	.472	.512	.564	.608	.641
OFF SOUTH							
VTN/DD B1	-.023	-.023	-.023	.270	.270	.270	.270
VTN/DD B2	-.117	-.117	-.117	-.119	-.119	-.119	-.119
A PARAM C1	1.203	1.066	.946	-.242	-.252	-.272	-.301
A PARAM C2	.090	.090	.092	.100	.099	.100	.104

CARIBOU, MAINE — LATITUDE = 46.9

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	19.22	15.85	13.48	11.72	10.37	9.30	8.42
VT2/DD	16.47	13.58	11.55	10.04	8.88	7.96	7.22
VT3/DD	14.31	11.80	10.03	8.73	7.72	6.92	6.27
ANNUAL DD	3285	4256	5369	6614	8011	9562	11228
PARAMETER A	.674	.740	.793	.838	.879	.915	.939
OFF SOUTH							
VTN/DD B1	.169	.169	.169	.169	.169	.169	.169
VTN/DD B2	-.114	-.114	-.114	-.114	-.114	-.114	-.114
A PARAM C1	.563	.558	.546	.529	.509	.489	.476
A PARAM C2	.039	.040	.041	.043	.045	.048	.052

PORTLAND, MAINE

LATITUDE = 43.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	33.77	26.30	21.38	17.76	15.16	13.23	11.73
VT2/DD	28.89	22.50	18.29	15.22	13.00	11.34	10.05
VT3/DD	25.10	19.55	15.89	13.23	11.29	9.85	8.74
ANNUAL DD	1831	2627	3583	4696	5975	7421	8997
PARAMETER A	.500	.544	.575	.620	.662	.700	.725
OFF SOUTH							
VTN/DD B1	-.822	-.822	-.822	.166	.166	.166	.166
VTN/DD B2	-.111	-.111	-.111	-.118	-.118	-.118	-.118
A PARAM C1	1.624	1.561	1.539	-1.384	-1.208	-1.061	-.951
A PARAM C2	.037	.044	.051	.079	.082	.085	.091

BALTIMORE, MARYLAND

LATITUDE = 39.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	68.86	48.65	36.94	29.65	24.06	20.05	17.18
VT2/DD	58.85	41.58	31.57	25.33	20.58	17.15	14.69
VT3/DD	51.11	36.11	27.42	22.00	17.87	14.09	12.76
ANNUAL DD	911	1479	2193	3036	4016	5136	6417
PARAMETER A	.587	.603	.592	.580	.607	.641	.675
OFF SOUTH							
VTN/DD B1	-.472	-.472	-.472	-.472	.483	.483	.483
VTN/DD B2	-.108	-.108	-.108	-.106	-.110	-.110	-.110
A PARAM C1	.996	1.025	1.081	1.116	-1.748	-1.644	-1.545
A PARAM C2	.034	.039	.047	.058	.071	.076	.080

PATUXENT RIVER, MARYLAND

LATITUDE = 38.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	95.07	63.91	46.15	35.59	28.85	24.13	20.70
VT2/DD	81.18	54.57	39.41	30.39	24.64	20.60	17.67
VT3/DD	70.50	47.39	34.22	26.39	21.39	17.89	15.35
ANNUAL DD	495	925	1512	2237	3098	4139	5363
PARAMETER A	.659	.662	.626	.606	.590	.594	.606
OFF SOUTH							
VTN/DD B1	-.216	-.216	-.216	-.216	-.216	-.216	-.216
VTN/DD B2	-.105	-.105	-.105	-.105	-.105	-.105	-.105
A PARAM C1	.225	.282	.339	.376	.412	.428	.418
A PARAM C2	.011	.019	.030	.039	.051	.062	.072

BOSTON, MASSACHUSETTS

LATITUDE = 42.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	48.03	33.92	26.16	21.25	17.85	15.37	13.50
VT2/DD	41.05	28.99	22.36	18.16	15.25	13.14	11.54
VT3/DD	35.65	25.18	19.42	15.77	13.25	11.41	10.02
ANNUAL DD	1040	1717	2537	3508	4643	5949	7410
PARAMETER A	.690	.686	.691	.696	.706	.718	.731
OFF SOUTH							
VTN/DD B1	-2.360	-2.360	-2.360	-2.360	-2.360	-2.360	-2.360
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	2.894	3.259	3.486	3.643	3.749	3.827	3.882
A PARAM C2	.025	.031	.039	.047	.055	.063	.070

ALPENA, MICHIGAN

LATITUDE = 45.0

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	16.81	12.80	10.34	8.67	7.46	6.55	5.84
VT2/DD	14.34	10.92	8.82	7.39	6.37	5.59	4.98
VT3/DD	12.45	9.48	7.65	6.42	5.53	4.85	4.32
ANNUAL DD	2433	3313	4337	5495	6777	8206	9780
PARAMETER A	.786	.906	.998	1.069	1.128	1.175	1.218
OFF SOUTH							
VTN/DD B1	.639	.639	.639	.639	.639	.639	.639
VTN/DD B2	-.096	-.096	-.096	-.096	-.096	-.096	-.096
A PARAM C1	-1.223	-.988	-.845	-.752	-.685	-.632	-.591
A PARAM C2	.014	.013	.013	.014	.015	.017	.018

DETROIT, MICHIGAN LATITUDE = 42.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	36.34	25.50	19.42	15.59	12.94	11.04	9.63
VT2/DD	31.03	21.77	16.58	13.31	11.05	9.43	8.22
VT3/DD	26.94	18.90	14.40	11.55	9.59	8.19	7.14
ANNUAL DD	1429	2116	2923	3849	4915	6115	7469
PARAMETER A	.447	.551	.629	.700	.766	.825	.880
OFF SOUTH							
VTN/DD B1	.432	.432	.432	.432	.432	.432	.432
VTN/DD B2	-.101	-.101	-.101	-.101	-.101	-.101	-.101
A PARAM C1	-1.205	-.908	-.740	-.618	-.522	-.449	-.392
A PARAM C2	.055	.048	.045	.043	.041	.041	.041

FLINT, MICHIGAN LATITUDE = 42.6

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	25.94	20.40	16.00	13.04	11.00	9.51	8.37
VT2/DD	22.16	17.42	13.66	11.14	9.39	8.12	7.15
VT3/DD	19.24	15.13	11.86	9.67	8.16	7.05	6.21
ANNUAL DD	1908	2681	3583	4617	5782	7101	8584
PARAMETER A	.572	.563	.630	.697	.758	.816	.870
OFF SOUTH							
VTN/DD B1	.346	.346	.672	.672	.672	.672	.672
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	-.448	-.625	-1.562	-1.450	-1.352	-1.256	-1.169
A PARAM C2	.049	.054	.052	.050	.049	.049	.049

GRAND RAPIDS, MICHIGAN LATITUDE = 42.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	26.31	19.22	15.14	12.49	10.63	9.25	8.19
VT2/DD	22.47	16.41	12.93	10.66	9.07	7.90	6.99
VT3/DD	19.51	14.25	11.22	9.26	7.88	6.86	6.07
ANNUAL DD	1793	2571	3469	4501	5654	6947	8393
PARAMETER A	.632	.727	.797	.860	.914	.965	1.011
OFF SOUTH							
VTN/DD B1	.845	.845	.845	.845	.845	.845	.845
VTN/DD B2	-.101	-.101	-.101	-.101	-.101	-.101	-.101
A PARAM C1	-1.631	-1.394	-1.253	-1.144	-1.063	-.995	-.940
A PARAM C2	.033	.031	.031	.031	.032	.032	.033

SAULT STE. MARIE, MICHIGAN LATITUDE = 46.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	14.09	11.98	10.43	9.23	8.28	7.50	6.86
VT2/DD	12.04	10.25	8.92	7.89	7.08	6.42	5.87
VT3/DD	10.46	8.90	7.74	6.85	6.15	5.57	5.10
ANNUAL DD	3170	4119	5200	6444	7847	9407	11082
PARAMETER A	.823	.847	.875	.910	.944	.975	.996
OFF SOUTH							
VTN/DD B1	-.680	-.680	-.680	-.680	-.680	-.680	-.680
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	.889	.928	.940	.933	.922	.911	.911
A PARAM C2	.021	.023	.026	.028	.030	.033	.036

TRAVERSE CITY, MICHIGAN LATITUDE = 44.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	18.70	14.83	12.29	10.49	9.15	8.11	7.29
VT2/DD	15.97	12.67	10.49	8.96	7.81	6.93	6.22
VT3/DD	13.87	11.00	9.11	7.78	6.78	6.01	5.40
ANNUAL DD	2161	3016	4003	5115	6357	7743	9277
PARAMETER A	.734	.755	.789	.822	.856	.890	.924
OFF SOUTH							
VTN/DD B1	.140	.140	.140	.140	.140	.140	.140
VTN/DD B2	-.101	-.101	-.101	-.101	-.101	-.101	-.101
A PARAM C1	.194	.209	.206	.196	.180	.164	.147
A PARAM C2	.031	.032	.033	.034	.035	.037	.039

DULUTH, MINNESOTA					LATITUDE = 46.5		
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	17.86	15.55	13.62	11.93	10.62	9.56	8.70
VT2/DD	15.30	13.33	11.68	10.24	9.11	8.21	7.47
VT3/DD	13.30	11.58	10.16	8.90	7.92	7.13	6.49
ANNUAL DD	3716	4704	5823	7081	8474	10013	11669
PARAMETER A	.610	.611	.637	.688	.734	.774	.803
OFF SOUTH							
VTN/DD B1	.167	.167	.909	.909	.909	.909	.909
VTN/DD B2	-.116	-.116	-.121	-.121	-.121	-.121	-.121
A PARAM C1	.493	.451	-1.780	-1.644	-1.535	-1.447	-1.391
A PARAM C2	.039	.046	.062	.068	.069	.071	.074

INTERNATIONAL FALLS, MINNESOTA					LATITUDE = 48.3		
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	14.11	12.38	10.83	9.61	8.62	7.82	7.15
VT2/DD	12.11	10.62	9.29	8.24	7.39	6.71	6.13
VT3/DD	10.52	9.23	8.07	7.16	6.43	5.83	5.33
ANNUAL DD	4331	5304	6402	7645	9040	10578	12229
PARAMETER A	.658	.690	.750	.810	.867	.916	.955
OFF SOUTH							
VTN/DD B1	-.023	.144	.144	.144	.144	.144	.144
VTN/DD B2	-.121	-.119	-.119	-.119	-.119	-.119	-.119
A PARAM C1	.369	-.078	-.075	-.080	-.088	-.096	-.104
A PARAM C2	.043	.039	.039	.039	.039	.041	.043

MINNEAPOLIS-ST. PAUL, MINNESOTA					LATITUDE = 44.5		
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	21.00	17.11	14.42	12.46	10.97	9.80	8.85
VT2/DD	17.98	14.65	12.35	10.67	9.39	8.39	7.58
VT3/DD	15.62	12.72	10.73	9.27	8.16	7.29	6.58
ANNUAL DD	2910	3731	4660	5706	6874	8179	9622
PARAMETER A	.645	.709	.768	.823	.873	.917	.957
OFF SOUTH							
VTN/DD B1	.088	.088	.088	.088	.088	.088	.088
VTN/DD B2	-.112	-.112	-.112	-.112	-.112	-.112	-.112
A PARAM C1	-.078	-.033	.002	.029	.050	.067	.078
A PARAM C2	.022	.024	.025	.027	.028	.031	.033

ROCHESTER, MINNESOTA					LATITUDE = 43.6		
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	24.19	20.13	16.96	14.64	12.88	11.50	10.38
VT2/DD	20.72	17.24	14.53	12.55	11.04	9.85	8.89
VT3/DD	18.00	14.98	12.63	10.90	9.59	8.56	7.73
ANNUAL DD	2843	3699	4656	5720	6909	8248	9762
PARAMETER A	.577	.600	.645	.686	.726	.764	.801
OFF SOUTH							
VTN/DD B1	.124	.837	.837	.837	.837	.837	.837
VTN/DD B2	-.113	-.116	-.116	-.116	-.116	-.116	-.116
A PARAM C1	.695	-1.533	-1.393	-1.283	-1.196	-1.125	-1.069
A PARAM C2	.035	.051	.051	.053	.055	.057	.060

JACKSON, MISSISSIPPI					LATITUDE = 32.2		
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	405.80	201.84	113.56	72.30	50.76	38.30	30.40
VT2/DD	346.35	171.71	96.61	61.51	43.19	32.58	25.86
VT3/DD	300.82	149.05	83.86	53.39	37.49	28.28	22.45
ANNUAL DD	195	413	757	1238	1851	2600	3528
PARAMETER A	.423	.506	.592	.626	.638	.643	.654
OFF SOUTH							
VTN/DD B1	.290	-.455	-.455	-.455	-.455	-.455	-.455
VTN/DD B2	-.105	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	-1.745	1.055	.842	.754	.708	.674	.638
A PARAM C2	.065	.018	.022	.027	.033	.040	.048

MERIDIAN, MISSISSIPPI — LATITUDE = 32.2

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	290.96	168.47	99.98	65.45	46.85	35.75	28.65
VT2/DD	245.42	142.10	85.03	55.66	39.85	30.40	24.37
VT3/DD	212.52	123.06	73.79	48.31	34.58	26.39	21.15
ANNUAL DD	243	474	825	1309	1950	2763	3747
PARAMETER A	.534	.466	.503	.562	.604	.624	.630
OFF SOUTH							
VTN/DD B1	.428	.428	.242	.242	.242	.242	.242
VTN/DD B2	-.067	-.067	-.092	-.092	-.092	-.092	-.092
A PARAM C1	-.296	-.397	.139	.078	.024	-.024	-.074
A PARAM C2	-.058	-.062	.036	.037	.039	.044	.053

COLUMBIA, MISSOURI — LATITUDE = 39.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	63.14	47.41	35.60	28.21	23.28	19.77	17.16
VT2/DD	53.99	40.54	30.47	24.14	19.92	16.92	14.69
VT3/DD	46.89	35.21	26.47	20.97	17.31	14.70	12.76
ANNUAL DD	1185	1750	2437	3243	4178	5263	6520
PARAMETER A	.465	.466	.525	.572	.609	.647	.682
OFF SOUTH							
VTN/DD B1	-.428	-.428	-.511	-.511	-.511	-.511	-.511
VTN/DD B2	-.112	-.112	-.115	-.115	-.115	-.115	-.115
A PARAM C1	.803	.948	1.219	1.187	1.167	1.136	1.106
A PARAM C2	.041	.047	.058	.059	.062	.065	.069

SPRINGFIELD, MISSOURI — LATITUDE = 37.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	104.39	69.82	51.24	40.01	32.58	27.28	23.43
VT2/DD	89.14	59.62	43.75	34.17	27.82	23.30	20.01
VT3/DD	77.42	51.78	38.00	29.67	24.16	20.23	17.38
ANNUAL DD	889	1403	2054	2833	3741	4790	6016
PARAMETER A	.404	.463	.477	.481	.485	.493	.505
OFF SOUTH							
VTN/DD B1	-.544	-.544	-.544	-.544	-.544	-.544	-.544
VTN/DD B2	-.106	-.106	-.106	-.106	-.106	-.106	-.106
A PARAM C1	.094	.078	.076	.072	.065	.068	.082
A PARAM C2	.049	.048	.054	.062	.072	.081	.092

ST. LOUIS, MISSOURI — LATITUDE = 38.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	64.17	45.27	34.06	26.96	22.16	18.78	16.29
VT2/DD	54.87	38.71	29.13	23.06	18.95	16.06	13.93
VT3/DD	47.66	33.62	25.30	20.03	16.46	13.95	12.10
ANNUAL DD	1068	1617	2290	3093	4020	5069	6257
PARAMETER A	.509	.574	.625	.662	.694	.721	.747
OFF SOUTH							
VTN/DD B1	-.981	-.981	-.981	-.981	-.981	-.981	-.981
VTN/DD B2	-.109	-.109	-.109	-.109	-.109	-.109	-.109
A PARAM C1	1.175	1.079	1.036	1.038	1.039	1.044	1.046
A PARAM C2	.045	.047	.048	.049	.051	.054	.058

BILLINGS, MONTANA — LATITUDE = 45.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	38.95	31.30	25.84	21.94	19.06	16.84	15.09
VT2/DD	33.45	26.88	22.19	18.85	16.37	14.47	12.96
VT3/DD	29.08	23.37	19.30	16.39	14.23	12.58	11.27
ANNUAL DD	2078	2844	3781	4865	6096	7464	8960
PARAMETER A	.640	.651	.663	.680	.699	.717	.730
OFF SOUTH							
VTN/DD B1	-.116	-.116	-.116	-.116	-.116	-.116	-.116
VTN/DD B2	-.126	-.126	-.126	-.126	-.126	-.126	-.126
A PARAM C1	-.066	.018	.091	.149	.193	.227	.254
A PARAM C2	.054	.062	.069	.074	.080	.086	.092

CUT BANK, MONTANA LATITUDE = 48.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	28.42	23.76	19.98	17.12	14.96	13.27	11.92
VT2/DD	24.42	20.42	17.17	14.72	12.85	11.40	10.25
VT3/DD	21.24	17.75	14.93	12.80	11.18	9.92	8.91
ANNUAL DD	2884	3810	4914	6180	7597	9135	10772
PARAMETER A	.669	.695	.740	.785	.824	.852	.867
OFF SOUTH							
VTN/DD B1	-.004	-.004	-.004	-.004	-.004	-.004	-.004
VTN/DD B2	-.128	-.128	-.128	-.128	-.128	-.128	-.128
A PARAM C1	.154	.145	.128	.110	.095	.085	.080
A PARAM C2	.045	.052	.056	.059	.063	.068	.074

DILLON, MONTANA LATITUDE = 45.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	42.69	33.97	27.93	23.69	20.57	18.18	16.28
VT2/DD	36.63	29.18	23.99	20.35	17.67	15.62	13.99
VT3/DD	31.84	25.37	20.86	17.69	15.36	13.58	12.16
ANNUAL DD	2374	3311	4404	5655	7052	8581	10195
PARAMETER A	.600	.623	.649	.667	.680	.684	.679
OFF SOUTH							
VTN/DD B1	.348	-.186	-.186	-.186	-.186	-.186	-.186
VTN/DD B2	-.122	-.127	-.127	-.127	-.127	-.127	-.127
A PARAM C1	-.686	.974	.978	.997	1.022	1.063	1.119
A PARAM C2	.050	.073	.080	.088	.096	.107	.120

GLASGOW, MONTANA LATITUDE = 48.1

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	22.34	18.78	16.20	14.24	12.70	11.47	10.45
VT2/DD	19.15	16.10	13.89	12.21	10.89	9.83	8.96
VT3/DD	16.65	13.99	12.07	10.61	9.46	8.54	7.78
ANNUAL DD	3285	4180	5188	6329	7589	8984	10508
PARAMETER A	.719	.730	.750	.777	.804	.832	.858
OFF SOUTH							
VTN/DD B1	.409	.409	.409	.409	.409	.409	.409
VTN/DD B2	-.117	-.117	-.117	-.117	-.117	-.117	-.117
A PARAM C1	-.349	-.344	-.338	-.330	-.324	-.317	-.309
A PARAM C2	.027	.030	.032	.034	.037	.039	.043

GREAT FALLS, MONTANA LATITUDE = 47.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	34.62	28.55	23.87	20.33	17.65	15.58	13.95
VT2/DD	29.69	24.49	20.47	17.44	15.14	13.36	11.96
VT3/DD	25.81	21.28	17.80	15.15	13.16	11.61	10.40
ANNUAL DD	2183	2940	3877	4994	6272	7697	9239
PARAMETER A	.812	.797	.781	.779	.784	.791	.794
OFF SOUTH							
VTN/DD B1	.271	.271	.271	.271	.271	.271	.271
VTN/DD B2	-.119	-.119	-.119	-.119	-.119	-.119	-.119
A PARAM C1	-.746	-.674	-.618	-.558	-.499	-.445	-.399
A PARAM C2	.033	.040	.047	.052	.058	.064	.070

HELENA, MONTANA LATITUDE = 46.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	28.29	22.88	19.17	16.49	14.46	12.88	11.61
VT2/DD	24.23	19.60	16.42	14.12	12.39	11.03	9.95
VT3/DD	21.05	17.03	14.27	12.27	10.76	9.59	8.64
ANNUAL DD	2253	3124	4154	5334	6673	8148	9725
PARAMETER A	.755	.783	.806	.829	.851	.868	.876
OFF SOUTH							
VTN/DD B1	-.038	-.038	-.038	-.038	-.038	-.038	-.038
VTN/DD B2	-.114	-.114	-.114	-.114	-.114	-.114	-.114
A PARAM C1	.353	.340	.329	.319	.312	.310	.312
A PARAM C2	.020	.025	.031	.036	.041	.046	.052

LEWISTOWN, MONTANA — LATITUDE = 47.0

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	16.39	14.39	12.79	11.49	10.40	9.48	8.70
VT2/DD	13.76	12.08	10.74	9.65	8.73	7.96	7.31
VT3/DD	11.89	10.44	9.28	8.34	7.54	6.88	6.31
ANNUAL DD	6060	7241	8522	9877	11300	12771	14280
PARAMETER A	1.049	1.048	1.041	1.033	1.024	1.013	1.000
OFF SOUTH							
VTN/DD B1	-.164	-.164	-.164	-.164	-.164	-.164	-.164
VTN/DD B2	-.005	-.005	-.005	-.005	-.005	-.005	-.005
A PARAM C1	.173	.213	.255	.296	.335	.372	.406
A PARAM C2	-.018	-.021	-.024	-.026	-.026	-.026	-.026

MILES CITY, MONTANA — LATITUDE = 46.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	28.27	23.78	20.48	17.97	16.01	14.43	13.14
VT2/DD	24.26	20.41	17.57	15.42	13.74	12.38	11.27
VT3/DD	21.09	17.74	15.27	13.40	11.94	10.76	9.80
ANNUAL DD	2800	3655	4630	5717	6923	8259	9715
PARAMETER A	.693	.700	.705	.711	.721	.733	.744
OFF SOUTH							
VTN/DD B1	-.077	-.077	-.077	-.077	-.077	-.077	-.077
VTN/DD B2	-.122	-.122	-.122	-.122	-.122	-.122	-.122
A PARAM C1	1.105	1.110	1.107	1.097	1.074	1.044	1.014
A PARAM C2	.033	.039	.045	.051	.057	.063	.069

MISSOULA, MONTANA — LATITUDE = 46.6

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	21.10	15.51	12.27	10.14	8.65	7.54	6.68
VT2/DD	18.01	13.24	10.47	8.66	7.38	6.43	5.70
VT3/DD	15.63	11.50	9.09	7.52	6.41	5.58	4.95
ANNUAL DD	1770	2681	3765	5012	6409	7925	9541
PARAMETER A	.866	.950	1.017	1.076	1.125	1.163	1.189
OFF SOUTH							
VTN/DD B1	-.907	-.907	-.907	-.907	-.907	-.907	-.907
VTN/DD B2	-.099	-.099	-.099	-.099	-.099	-.099	-.099
A PARAM C1	1.003	.898	.829	.776	.738	.717	.709
A PARAM C2	.009	.011	.013	.015	.017	.019	.021

GRAND ISLAND, NEBRASKA — LATITUDE = 40.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	47.78	38.74	32.35	27.70	24.20	21.48	19.31
VT2/DD	40.93	33.18	27.71	23.73	20.72	18.40	16.54
VT3/DD	35.57	28.83	24.08	20.62	18.01	15.99	14.37
ANNUAL DD	1989	2717	3565	4535	5616	6829	8189
PARAMETER A	.529	.538	.544	.549	.552	.559	.565
OFF SOUTH							
VTN/DD B1	-.504	-.504	-.504	-.504	-.504	-.504	-.504
VTN/DD B2	-.117	-.117	-.117	-.117	-.117	-.117	-.117
A PARAM C1	1.034	1.089	1.126	1.148	1.158	1.147	1.129
A PARAM C2	.038	.046	.055	.064	.074	.085	.097

NORTH PLATTE, NEBRASKA — LATITUDE = 41.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	50.70	41.03	34.24	29.33	25.64	22.77	20.47
VT2/DD	43.42	35.14	29.33	25.12	21.96	19.50	17.53
VT3/DD	37.73	30.54	25.48	21.83	19.08	16.94	15.24
ANNUAL DD	2168	2958	3871	4900	6048	7336	8768
PARAMETER A	.623	.586	.563	.552	.551	.552	.552
OFF SOUTH							
VTN/DD B1	.106	.106	.106	.106	.106	.106	.106
VTN/DD B2	-.116	-.116	-.116	-.116	-.116	-.116	-.116
A PARAM C1	-.791	-.854	-.892	-.906	-.902	-.893	-.889
A PARAM C2	.045	.056	.066	.076	.086	.096	.109

OMAHA, NEBRASKA — LATITUDE = 41.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M=12)
VT1/DD	47.07	37.98	31.57	26.97	23.55	20.90	18.42
VT2/DD	40.28	32.50	27.01	23.08	20.15	17.88	15.78
VT3/DD	35.00	28.23	23.47	20.06	17.51	15.54	13.71
ANNUAL DD	1753	2397	3161	4051	5064	6197	7485
PARAMETER A	.473	.487	.502	.513	.522	.531	.570
OFF SOUTH							
VTN/DD B1	.122	.122	.122	.122	.122	.122	.252
VTN/DD B2	-.112	-.112	-.112	-.112	-.112	-.112	-.118
A PARAM C1	.775	.724	.661	.596	.543	.498	-.004
A PARAM C2	.028	.034	.040	.046	.054	.062	.089

SCOTTSBLUFF, NEBRASKA — LATITUDE = 41.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	58.22	46.05	37.70	31.77	27.24	23.69	20.96
VT2/DD	49.87	39.45	32.30	27.22	23.38	20.34	17.99
VT3/DD	43.34	34.28	28.07	23.66	20.32	17.68	15.64
ANNUAL DD	2011	2806	3749	4813	6000	7328	8792
PARAMETER A	.585	.552	.532	.520	.515	.522	.526
OFF SOUTH							
VTN/DD B1	-.227	-.227	-.227	-.227	-.285	-.285	-.285
VTN/DD B2	-.117	-.117	-.117	-.117	-.125	-.125	-.125
A PARAM C1	334	.401	.454	.500	.786	.807	.830
A PARAM C2	.052	.066	.080	.093	.137	.148	.160

ELKO, NEVADA — LATITUDE = 40.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	58.99	45.55	37.02	31.17	26.92	23.69	21.16
VT2/DD	50.62	39.08	31.76	26.75	23.10	20.33	18.15
VT3/DD	44.00	33.98	27.61	23.25	20.08	17.67	15.78
ANNUAL DD	1829	2693	3708	4872	6164	7570	9073
PARAMETER A	.793	.785	.772	.756	.736	.712	.684
OFF SOUTH							
VTN/DD B1	-.195	-.195	-.195	-.195	-.195	-.195	-.195
VTN/DD B2	-.124	-.124	-.124	-.124	-.124	-.124	-.124
A PARAM C1	.248	.351	.451	.548	.642	.734	.828
A PARAM C2	.039	.052	.066	.080	.096	.114	.134

ELY, NEVADA — LATITUDE = 39.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	64.22	50.47	41.28	34.87	30.17	26.59	23.77
VT2/DD	54.98	43.20	35.34	29.85	25.83	22.77	20.35
VT3/DD	47.77	37.54	30.71	25.93	22.44	19.78	17.68
ANNUAL DD	2202	3081	4107	5295	6622	8079	9642
PARAMETER A	.641	.634	.624	.613	.597	.574	.543
OFF SOUTH							
VTN/DD B1	-.580	-.580	-.580	-.580	-.580	-.580	-.580
VTN/DD B2	-.115	-.115	-.115	-.115	-.115	-.115	-.115
A PARAM C1	1.970	2.068	2.166	2.268	2.397	2.575	2.813
A PARAM C2	.057	.072	.088	.106	.126	.149	.178

LAS VEGAS, NEVADA — LATITUDE = 36.1

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	814.29	333.12	172.83	108.38	76.34	58.42	47.29
VT2/DD	697.07	285.56	148.15	92.91	65.44	50.08	40.54
VT3/DD	605.82	248.22	128.78	80.76	56.88	43.53	35.24
ANNUAL DD	131	332	664	1161	1831	2658	3625
PARAMETER A	.414	.435	.538	.590	.615	.617	.608
OFF SOUTH							
VTN/DD B1	.146	.273	.273	.273	.273	.273	.273
VTN/DD B2	-.119	-.123	-.123	-.123	-.123	-.123	-.123
A PARAM C1	.077	-.532	-.435	-.413	-.406	-.413	-.425
A PARAM C2	.016	.038	.034	.041	.055	.072	.092

LOVELOCK, NEVADA LATITUDE = 40.0

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	92.15	69.14	54.19	44.04	36.97	31.83	27.92
VT2/DD	78.90	59.20	46.41	37.71	31.65	27.25	23.91
VT3/DD	68.57	51.45	40.33	32.77	27.51	23.68	20.78
ANNUAL DD	1322	1926	2818	3811	4953	6232	7627
PARAMETER A	.677	.681	.668	.652	.637	.622	.603
OFF SOUTH							
VTN/DD B1	-.226	-.226	-.226	-.226	-.226	-.226	-.226
VTN/DD B2	-.116	-.116	-.116	-.116	-.116	-.116	-.116
A PARAM C1	.681	.783	.888	.983	1.063	1.134	1.206
A PARAM C2	.019	.031	.047	.063	.081	.099	.120

RENO, NEVADA LATITUDE = 39.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	106.87	75.31	56.67	45.03	37.16	31.60	27.49
VT2/DD	91.68	64.61	48.62	38.63	31.88	27.11	23.59
VT3/DD	79.70	56.16	42.26	33.58	27.71	23.57	20.50
ANNUAL DD	1162	1874	2771	3831	5052	6416	7893
PARAMETER A	.800	.768	.749	.730	.709	.681	.646
OFF SOUTH							
VTN/DD B1	.410	.410	.410	.410	.410	.410	.410
VTN/DD B2	-.124	-.124	-.124	-.124	-.124	-.124	-.124
A PARAM C1	-.271	-.337	-.389	-.437	-.483	-.533	-.587
A PARAM C2	.044	.061	.077	.094	.112	.133	.159

TONOPAH, NEVADA LATITUDE = 38.0

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	122.69	89.97	68.65	54.46	45.13	38.53	33.61
VT2/DD	105.13	77.09	58.92	46.74	38.73	33.07	28.85
VT3/DD	91.38	67.01	51.22	40.63	33.67	28.75	25.08
ANNUAL DD	1166	1836	2664	3649	4783	6060	7472
PARAMETER A	.642	.595	.570	.558	.539	.519	.495
OFF SOUTH							
VTN/DD B1	-.132	-.132	.429	.429	.429	.429	.429
VTN/DD B2	-.120	-.120	-.126	-.126	-.126	-.126	-.126
A PARAM C1	.830	.955	-.847	-.841	-.848	-.857	-.874
A PARAM C2	.044	.066	.108	.129	.152	.177	.209

WINNEMUCCA, NEVADA LATITUDE = 40.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	84.80	60.90	46.71	37.76	31.67	27.27	23.94
VT2/DD	72.64	52.16	40.01	32.34	27.13	23.36	20.51
VT3/DD	63.13	45.33	34.77	28.11	23.57	20.30	17.82
ANNUAL DD	1466	2228	3154	4236	5464	6811	8258
PARAMETER A	.700	.702	.702	.698	.686	.669	.648
OFF SOUTH							
VTN/DD B1	.007	.007	.007	.007	.007	.007	.007
VTN/DD B2	-.118	-.118	-.118	-.118	-.118	-.118	-.118
A PARAM C1	.522	.558	.579	.603	.631	.665	.703
A PARAM C2	.043	.055	.065	.077	.090	.106	.124

YUCCA FLATS, NEVADA LATITUDE = 36.6

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	133.69	92.76	69.12	54.11	44.21	37.34	32.32
VT2/DD	114.63	79.54	59.27	46.40	37.91	32.02	27.71
VT3/DD	99.65	69.14	51.52	40.33	32.95	27.83	24.09
ANNUAL DD	906	1452	2152	3018	4043	5202	6486
PARAMETER A	.753	.742	.732	.712	.687	.658	.626
OFF SOUTH							
VTN/DD B1	.122	.122	.122	.122	.122	.122	.122
VTN/DD B2	-.124	-.124	-.124	-.124	-.124	-.124	-.124
A PARAM C1	.158	.181	.210	.242	.276	.310	.345
A PARAM C2	.050	.060	.073	.088	.105	.125	.147

CONCORD, NEW HAMPSHIRE — LATITUDE = 43.1

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	23.53	18.43	15.09	12.75	11.02	9.70	8.66
VT2/DD	20.11	15.76	12.90	10.90	9.42	8.29	7.40
VT3/DD	17.47	13.69	11.20	9.47	8.18	7.20	6.43
ANNUAL DD	2149	2960	3909	4991	6213	7582	9092
PARAMETER A	.743	.806	.854	.892	.929	.960	.986
OFF SOUTH							
VTN/DD B1	.000	.000	.000	.000	.000	.000	.000
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	-.316	-.244	-.193	-.155	-.125	-.102	-.083
A PARAM C2	.026	.028	.030	.032	.034	.037	.040

LAKEHURST, NEW JERSEY — LATITUDE = 40.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	62.01	44.39	34.17	27.54	21.88	18.10	15.41
VT2/DD	52.98	37.93	29.20	23.53	18.70	15.46	13.17
VT3/DD	46.01	32.94	25.36	20.43	16.24	13.43	11.44
ANNUAL DD	986	1584	2334	3232	4285	5497	6857
PARAMETER A	.585	.582	.570	.575	.648	.702	.746
OFF SOUTH							
VTN/DD B1	-.218	-.218	-.218	.413	.413	.413	.413
VTN/DD B2	-.107	-.107	-.107	-.106	-.106	-.106	-.106
A PARAM C1	.722	.835	.922	-.981	-.823	-.724	-.659
A PARAM C2	.039	.048	.059	.065	.065	.066	.068

NEWARK, NEW JERSEY — LATITUDE = 40.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	68.92	47.20	35.20	27.92	23.10	19.66	17.12
VT2/DD	58.91	40.34	30.09	23.86	19.74	16.81	14.63
VT3/DD	51.17	35.04	26.13	20.73	17.15	14.60	12.71
ANNUAL DD	823	1400	2125	2982	3972	5105	6421
PARAMETER A	.524	.531	.532	.536	.548	.565	.590
OFF SOUTH							
VTN/DD B1	.236	.236	.236	.236	.236	.236	.236
VTN/DD B2	-.109	-.109	-.109	-.109	-.109	-.109	-.109
A PARAM C1	-.147	-.235	-.304	-.341	-.359	-.376	-.390
A PARAM C2	.033	.045	.055	.064	.072	.079	.086

ALBUQUERQUE, NEW MEXICO — LATITUDE = 35.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	187.35	116.10	81.07	61.58	49.51	41.38	35.55
VT2/DD	160.10	99.21	69.28	52.62	42.31	35.36	30.38
VT3/DD	139.09	86.20	60.19	45.71	36.76	30.72	26.39
ANNUAL DD	753	1257	1925	2734	3677	4784	6074
PARAMETER A	.416	.468	.501	.508	.503	.501	.503
OFF SOUTH							
VTN/DD B1	.219	.219	.219	.219	.219	.219	.219
VTN/DD B2	-.110	-.110	-.110	-.110	-.110	-.110	-.110
A PARAM C1	.089	.069	.051	.041	.036	.038	.051
A PARAM C2	.068	.063	.066	.077	.093	.110	.130

CLAYTON, NEW MEXICO — LATITUDE = 36.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	142.75	102.11	76.89	60.69	49.68	41.90	36.20
VT2/DD	122.32	87.50	65.88	52.00	42.57	35.90	31.02
VT3/DD	106.33	76.05	57.27	45.20	37.00	31.21	26.96
ANNUAL DD	1023	1561	2241	3062	4036	5191	6533
PARAMETER A	.447	.444	.437	.429	.422	.418	.411
OFF SOUTH							
VTN/DD B1	-.042	-.042	-.042	-.042	-.042	-.042	-.042
VTN/DD B2	-.119	-.119	-.119	-.119	-.119	-.119	-.119
A PARAM C1	.227	.276	.342	.413	.477	.540	.599
A PARAM C2	.105	.114	.126	.141	.162	.188	.219

ROSWELL, NEW MEXICO — LATITUDE = 33.2

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	216.84	138.09	97.26	73.39	58.06	47.60	40.16
VT2/DD	185.60	116.19	83.24	62.81	49.69	40.74	34.37
VT3/DD	161.30	102.72	72.35	54.59	43.19	35.41	29.87
ANNUAL DD	553	949	1488	2171	2990	3960	5101
PARAMETER A	.584	.581	.583	.572	.550	.532	.517
OFF SOUTH							
VTN/DD B1	-.353	-.353	-.353	-.353	-.353	-.353	-.353
VTN/DD B2	-.118	-.118	-.118	-.118	-.118	-.118	-.118
A PARAM C1	.468	.494	.528	.590	.669	.741	.802
A PARAM C2	.058	.064	.075	.090	.109	.130	.153

TRUTH OR CONSEQ., NEW MEXICO — LATITUDE = 33.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	199.58	133.29	95.42	72.22	57.28	47.19	40.07
VT2/DD	170.45	113.83	81.49	61.67	48.92	40.30	34.22
VT3/DD	148.09	98.90	70.80	53.59	42.50	35.02	29.73
ANNUAL DD	511	823	1394	2062	2888	3878	5050
PARAMETER A	.727	.700	.674	.650	.617	.584	.561
OFF SOUTH							
VTN/DD B1	.008	.008	.008	.008	.008	.008	.008
VTN/DD B2	-.110	-.110	-.110	-.110	-.110	-.110	-.110
A PARAM C1	.188	.257	.315	.367	.424	.484	.534
A PARAM C2	.012	.019	.027	.039	.057	.079	.103

TUCUMCARI, NEW MEXICO — LATITUDE = 35.1

DUE SOUTH	TR40 (M= 2)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	220.32	141.13	99.65	75.08	59.42	48.84	41.39
VT2/DD	186.77	120.60	85.15	64.16	50.78	41.73	35.37
VT3/DD	161.93	104.78	73.98	55.74	44.12	36.26	30.73
ANNUAL DD	693	1146	1735	2466	3339	4366	5573
PARAMETER A	.293	.346	.372	.382	.384	.385	.386
OFF SOUTH							
VTN/DD B1	.346	.139	.139	.139	.139	.139	.139
VTN/DD B2	-.084	-.110	-.110	-.110	-.110	-.110	-.110
A PARAM C1	-1.005	.049	-.008	-.050	-.082	-.109	-.133
A PARAM C2	-.080	.081	.089	.102	.121	.143	.169

ALBANY, NEW YORK — LATITUDE = 42.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	36.32	28.64	23.41	19.02	16.01	13.82	12.16
VT2/DD	31.09	24.52	20.03	16.27	13.70	11.82	10.40
VT3/DD	27.01	21.30	17.40	14.13	11.90	10.27	9.04
ANNUAL DD	1868	2645	3528	4519	5633	6886	8305
PARAMETER A	.556	.544	.554	.619	.673	.722	.769
OFF SOUTH							
VTN/DD B1	.081	.081	.172	.172	.172	.172	.172
VTN/DD B2	-.114	-.114	-.111	-.111	-.111	-.111	-.111
A PARAM C1	.192	.257	-.001	.035	.059	.074	.082
A PARAM C2	.057	.067	.061	.061	.062	.063	.065

BINGHAMTON, NEW YORK — LATITUDE = 42.1

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	18.45	14.15	11.42	9.53	8.13	7.07	6.25
VT2/DD	15.70	12.05	9.72	8.11	6.92	6.01	5.32
VT3/DD	13.62	10.45	8.43	7.04	6.00	5.22	4.61
ANNUAL DD	2172	3011	3950	5008	6199	7549	9071
PARAMETER A	.679	.753	.808	.861	.917	.974	1.028
OFF SOUTH							
VTN/DD B1	1.013	1.013	1.013	1.013	1.013	1.013	1.013
VTN/DD B2	-.087	-.087	-.087	-.087	-.087	-.087	-.087
A PARAM C1	-1.523	-1.402	-1.323	-1.248	-1.167	-1.086	-1.014
A PARAM C2	.019	.020	.021	.022	.023	.023	.024

BUFFALO, NEW YORK LATITUDE = 42.6

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	22.01	16.39	12.55	10.13	8.47	7.26	6.36
VT2/DD	18.74	13.96	10.69	8.62	7.21	6.18	5.41
VT3/DD	16.26	12.11	9.27	7.48	6.25	5.36	4.70
ANNUAL DD	1684	2433	3321	4346	5515	6830	8306
PARAMETER A	.586	.641	.731	.806	.873	.933	.988
OFF SOUTH							
VTN/DD B1	.828	.314	.314	.314	.314	.314	.314
VTN/DD B2	-.088	-.088	-.088	-.088	-.088	-.088	-.088
A PARAM C1	-.768	.514	.395	.321	.265	.221	.186
A PARAM C2	.038	.035	.032	.030	.029	.029	.029

MASSENA, NEW YORK LATITUDE = 44.6

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M=12)	TR70 (M=12)
VT1/DD	20.22	16.89	14.50	12.70	11.30	10.07	9.02
VT2/DD	17.29	14.44	12.40	10.86	9.66	8.62	7.72
VT3/DD	15.02	12.54	10.77	9.43	8.39	7.49	6.71
ANNUAL DD	2746	3631	4640	5772	7030	8436	9985
PARAMETER A	.706	.720	.741	.762	.[illegible]6	.822	.864
OFF SOUTH							
VTN/DD B1	-.178	-.178	-.178	-.178	-.178	.963	.963
VTN/DD B2	-.108	-.108	-.108	-.108	-.108	-.111	-.111
A PARAM C1	1.173	1.147	1.106	1.058	1.007	-1.351	-1.272
A PARAM C2	.028	.032	.035	.038	.041	.053	.054

NEW YORK (LA GUARDIA), NEW YORK LATITUDE = 40.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M=12)
VT1/DD	66.42	45.08	33.45	26.52	21.90	18.62	16.02
VT2/DD	56.75	38.52	28.58	22.65	18.71	15.91	13.70
VT3/DD	49.28	33.45	24.82	19.67	16.25	13.82	11.90
ANNUAL DD	782	1328	2029	2861	3849	4998	6316
PARAMETER A	.557	.537	.541	.537	.546	.556	.584
OFF SOUTH							
VTN/DD B1	-.392	-.392	-.392	-.392	-.392	-.392	-.125
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.112
A PARAM C1	.931	1.007	1.031	1.074	1.080	1.080	.224
A PARAM C2	.037	.047	.055	.064	.073	.082	.106

NEW YORK (CENTAL PARK), NEW YORK LATITUDE = 40.8

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	70.00	45.26	32.78	25.62	20.52	16.85	14.29
VT2/DD	59.89	38.72	28.04	21.92	17.57	14.42	12.23
VT3/DD	52.02	33.63	24.36	19.04	15.26	12.53	10.62
ANNUAL DD	781	1330	2041	2908	3914	5085	6473
PARAMETER A	.448	.459	.465	.487	.547	.622	.689
OFF SOUTH							
VTN/DD B1	-1.276	-1.276	-1.276	-1.276	-.431	-.431	-.431
VTN/DD B2	-.113	-.113	-.113	-.113	-.114	-.114	-.114
A PARAM C1	2.763	3.277	3.844	4.158	1.142	1.189	1.197
A PARAM C2	.063	.069	.074	.079	.081	.080	.081

ROCHESTER, NEW YORK LATITUDE = 43.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	19.87	15.52	12.63	10.29	8.68	7.51	6.61
VT2/DD	16.93	13.22	10.77	8.77	7.40	6.40	5.64
VT3/DD	14.69	11.47	9.35	7.61	6.42	5.55	4.89
ANNUAL DD	1873	2656	3565	4608	5781	7110	8583
PARAMETER A	.644	.676	.719	.807	.879	.942	.997
OFF SOUTH							
VTN/DD B1	-.285	-.285	-.751	-.751	-.751	-.751	-.751
VTN/DD B2	-.090	-.090	-.094	-.094	-.094	-.094	-.094
A PARAM C1	-.809	-.751	.390	.353	.335	.326	.323
A PARAM C2	.022	.023	.035	.033	.032	.031	.032

SYRACUSE, NEW YORK — LATITUDE = 43.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	20.89	16.59	13.75	11.67	9.85	8.48	7.44
VT2/DD	17.81	14.14	11.72	9.95	8.39	7.23	6.34
VT3/DD	15.46	12.28	10.17	8.63	7.28	6.28	5.50
ANNUAL DD	1894	2641	3513	4512	5669	6983	8449
PARAMETER A	.578	.611	.643	.678	.755	.825	.887
OFF SOUTH							
VTN/DD B1	-.083	-.083	-.083	.130	.130	.130	.130
VTN/DD B2	-.094	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	-.251	-.268	-.270	-.772	-.673	-.593	-.529
A PARAM C2	.036	.037	.038	.037	.036	.035	.035

ASHEVILLE, NORTH CAROLINA — LATITUDE = 35.3

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	149.04	93.38	64.32	47.63	37.39	30.64	25.95
VT2/DD	126.19	79.07	54.45	40.33	31.66	25.94	21.97
VT3/DD	109.38	68.53	47.20	34.95	27.44	22.49	19.05
ANNUAL DD	655	1095	1668	2419	3372	4536	5936
PARAMETER A	.441	.449	.474	.486	.494	.505	.517
OFF SOUTH							
VTN/DD B1	.288	.288	.288	.288	.288	.288	.288
VTN/DD B2	-.078	-.078	-.078	-.078	-.078	-.078	-.078
A PARAM C1	-.785	-.827	-.820	-.851	-.903	-.943	-.977
A PARAM C2	-.041	-.034	-.027	-.019	-.008	.007	.026

CAPE HATTERAS, NORTH CAROLINA — LATITUDE = 35.3

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	416.30	207.61	121.41	81.01	57.85	43.11	34.09
VT2/DD	352.70	175.90	102.87	68.64	49.01	36.76	29.07
VT3/DD	305.79	152.50	89.18	59.51	42.49	31.92	25.24
ANNUAL DD	152	355	700	1212	1881	2739	3787
PARAMETER A	.529	.533	.458	.389	.383	.408	.434
OFF SOUTH							
VTN/DD B1	-.580	-.580	-.580	-.580	-.580	-.122	-.122
VTN/DD B2	-.082	-.082	-.082	-.08[illegible]	-.082	-.100	-.100
A PARAM C1	.473	.573	.877	1.353	1.637	-.179	.003
A PARAM C2	-.047	-.044	-.046	-.040	-.023	.079	.094

CHARLOTTE, NORTH CAROLINA — LATITUDE = 35.1

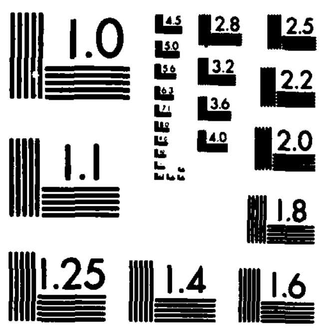
DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	164.16	106.26	75.30	55.28	42.39	33.88	27.94
VT2/DD	138.90	89.91	63.71	46.77	35.87	28.66	23.64
VT3/DD	120.37	77.92	55.22	40.53	31.08	24.84	20.49
ANNUAL DD	464	798	1265	1875	2641	3574	4708
PARAMETER A	.539	.509	.475	.468	.469	.483	.519
OFF SOUTH							
VTN/DD B1	.587	.587	.587	.587	.587	.587	.587
VTN/DD B2	-.073	-.073	-.073	-.073	-.073	-.073	-.073
A PARAM C1	-.847	-.990	-1.146	-1.233	-1.301	-1.320	-1.269
A PARAM C2	-.062	-.063	-.062	-.056	-.048	-.037	-.021

CHERRY POINT, NORTH CAROLINA — LATITUDE = 34.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	371.78	197.07	119.32	80.65	59.08	45.41	36.31
VT2/DD	317.15	168.11	101.79	68.80	50.40	38.74	30.98
VT3/DD	275.42	145.99	88.40	59.74	43.77	33.64	26.90
ANNUAL DD	184	412	764	1260	1899	2708	3732
PARAMETER A	.620	.560	.519	.484	.462	.454	.466
OFF SOUTH							
VTN/DD B1	-.657	-.657	-.657	-.657	-.657	-.657	-.657
VTN/DD B2	-.104	-.104	-.104	-.104	-.104	-.104	-.104
A PARAM C1	.558	.888	1.120	1.328	1.494	1.626	1.687
A PARAM C2	.027	.034	.041	.053	.066	.080	.097

AD-A147 181 DEVELOPMENT OF DESIGN AND ECONOMIC PARAMETERS FOR PASSIVE SOLAR SYSTEMS(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. 3/3

UNCLASSIFIED R A WOODS ET AL. SEP 84 AFIT/GEM/LSM/84S-10 F/G 10/2 NL


1.0
2.8
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1.6

GREENSBORO, NORTH CAROLINA — LATITUDE = 36.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	162.56	100.21	68.86	51.38	40.38	32.49	27.17
VT2/DD	138.78	85.55	58.79	43.86	34.19	27.51	23.01
VT3/DD	120.53	74.30	51.06	38.10	29.64	23.84	19.95
ANNUAL DD	515	929	1487	2183	3022	4023	5215
PARAMETER A	.513	.455	.444	.450	.470	.509	.539
OFF SOUTH							
VTN/DD B1	.737	.737	.737	.737	.416	.416	.416
VTN/DD B2	-.105	-.105	-.105	-.105	-.077	-.077	-.077
A PARAM C1	-.938	-1.171	-1.304	-1.386	-.069	-.176	-.281
A PARAM C2	.038	.049	.057	.064	-.038	-.024	-.009

RALEIGH-DURHAM, NORTH CAROLINA — LATITUDE = 35.5

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	151.96	99.67	63.67	44.84	33.74	26.80	22.16
VT2/DD	128.65	84.38	54.22	38.18	28.73	22.83	18.87
VT3/DD	111.53	73.15	47.06	33.14	24.94	19.81	16.38
ANNUAL DD	468	841	1346	1981	2780	3753	4910
PARAMETER A	.543	.437	.504	.554	.598	.626	.647
OFF SOUTH							
VTN/DD B1	.390	.390	-.362	-.362	-.362	-.362	-.362
VTN/DD B2	-.076	-.076	-.096	-.096	-.096	-.096	-.096
A PARAM C1	-1.097	-1.413	1.244	1.104	1.008	.955	.911
A PARAM C2	-.033	-.039	.040	.041	.044	.051	.059

BISMARCK, NORTH DAKOTA — LATITUDE = 46.8

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	24.93	21.17	18.38	16.16	14.42	13.01	11.86
VT2/DD	21.36	18.14	15.75	13.87	12.37	11.17	10.18
VT3/DD	18.56	15.76	13.69	12.06	10.76	9.71	8.85
ANNUAL DD	3413	4330	5365	6522	7789	9166	10680
PARAMETER A	.564	.585	.611	.642	.670	.694	.717
OFF SOUTH							
VTN/DD B1	-.305	-.305	-.305	.314	.314	.314	.314
VTN/DD B2	-.115	-.115	-.115	-.121	-.121	-.121	-.121
A PARAM C1	.577	.606	.622	-1.145	-1.044	-.959	-.883
A PARAM C2	.038	.042	.046	.068	.071	.074	.078

FARGO, NORTH DAKOTA — LATITUDE = 46.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	17.24	15.14	13.50	12.18	11.10	10.19	9.42
VT2/DD	14.78	12.98	11.58	10.44	9.51	8.74	8.08
VT3/DD	12.84	11.28	10.06	9.08	8.27	7.59	7.02
ANNUAL DD	3734	4643	5650	6775	8027	9408	10905
PARAMETER A	.677	.692	.712	.738	.768	.798	.823
OFF SOUTH							
VTN/DD B1	.432	.432	.432	.432	.432	.432	.432
VTN/DD B2	-.118	-.118	-.118	-.118	-.118	-.118	-.118
A PARAM C1	-.424	-.445	-.450	-.442	-.429	-.416	-.407
A PARAM C2	.031	.035	.038	.041	.044	.047	.050

MINOT, NORTH DAKOTA — LATITUDE = 48.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	18.08	15.61	13.73	12.25	11.06	10.09	9.27
VT2/DD	15.51	13.39	11.78	10.51	9.49	8.65	7.95
VT3/DD	13.48	11.64	10.24	9.14	8.25	7.52	6.91
ANNUAL DD	3486	4426	5477	6641	7939	9373	10926
PARAMETER A	.731	.755	.777	.803	.830	.858	.881
OFF SOUTH							
VTN/DD B1	-.126	-.126	-.126	-.126	-.126	-.126	-.126
VTN/DD B2	-.120	-.120	-.120	-.120	-.120	-.120	-.120
A PARAM C1	.911	.895	.878	.856	.831	.806	.786
A PARAM C2	.027	.030	.034	.037	.040	.044	.047

AKRON-CANTON, OHIO LATITUDE = 40.1

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	30.49	23.03	17.80	14.43	12.06	10.30	8.98
VT2/DD	26.02	19.65	15.18	12.32	10.29	8.79	7.66
VT3/DD	22.59	17.06	13.18	10.69	8.94	7.63	6.65
ANNUAL DD	1516	2204	3019	3977	5092	6358	7774
PARAMETER A	.563	.602	.684	.757	.823	.881	.930
OFF SOUTH							
VTN/DD B1	.106	.630	.630	.630	.630	.630	.630
VTN/DD B2	-.102	-.099	-.099	-.099	-.099	-.099	-.099
A PARAM C1	.862	-.732	-.660	-.604	-.562	-.529	-.506
A PARAM C2	.041	.036	.036	.036	.037	.038	.040

CINCINNATI, OHIO LATITUDE = 39.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	40.12	30.18	23.73	19.42	16.34	14.08	12.36
VT2/DD	34.21	25.73	20.23	16.56	13.93	12.00	10.54
VT3/DD	29.69	22.34	17.56	14.37	12.09	10.42	9.15
ANNUAL DD	1055	1634	2335	3162	4126	5250	6563
PARAMETER A	.869	.817	.784	.764	.762	.774	.795
OFF SOUTH							
VTN/DD B1	-.755	-.755	-.755	-.755	-.755	-.755	-.755
VTN/DD B2	-.098	-.098	-.098	-.098	-.098	-.098	-.098
A PARAM C1	1.231	1.492	1.656	1.757	1.783	1.757	1.704
A PARAM C2	.021	.028	.033	.037	.041	.044	.048

COLUMBUS, OHIO LATITUDE = 40.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M=12)	TR70 (M=12)
VT1/DD	40.68	29.89	23.32	19.01	16.01	13.46	11.60
VT2/DD	34.69	25.49	19.89	16.21	13.65	11.49	9.90
VT3/DD	30.11	22.13	17.27	14.07	11.85	9.98	8.60
ANNUAL DD	1216	1832	2576	3462	4507	5722	7112
PARAMETER A	.615	.605	.611	.628	.654	.716	.772
OFF SOUTH							
VTN/DD B1	.268	.268	.268	.268	.268	.816	.816
VTN/DD B2	-.098	-.098	-.098	-.098	-.098	-.101	-.101
A PARAM C1	.696	.718	.705	.668	.613	-.750	-.703
A PARAM C2	.034	.037	.040	.043	.046	.054	.058

DAYTON, OHIO LATITUDE = 39.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	37.59	27.15	20.95	16.86	14.02	11.97	10.44
VT2/DD	32.06	23.16	17.87	14.38	11.95	10.21	8.90
VT3/DD	27.83	20.10	15.52	12.48	10.38	8.86	7.73
ANNUAL DD	1315	1935	2678	3559	4572	5729	7063
PARAMETER A	.655	.707	.746	.788	.827	.867	.912
OFF SOUTH							
VTN/DD B1	.667	.667	.667	.667	.667	.667	.667
VTN/DD B2	-.098	-.098	-.098	-.098	-.098	-.098	-.098
A PARAM C1	-.979	-.858	-.774	-.701	-.645	-.599	-.558
A PARAM C2	.026	.028	.030	.031	.033	.034	.036

TOLEDO, OHIO LATITUDE = 41.4

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	29.31	21.70	17.04	13.87	11.68	10.05	8.83
VT2/DD	25.01	18.52	14.54	11.83	9.95	8.57	7.53
VT3/DD	21.71	16.08	12.62	10.27	8.63	7.44	6.54
ANNUAL DD	1644	2373	3242	4235	5364	6637	8071
PARAMETER A	.700	.761	.821	.882	.933	.978	1.019
OFF SOUTH							
VTN/DD B1	.645	.645	.645	.645	.645	.645	.645
VTN/DD B2	-.100	-.100	-.100	-.100	-.100	-.100	-.100
A PARAM C1	-1.689	-1.538	-1.381	-1.233	-1.118	-1.025	-.949
A PARAM C2	.023	.024	.025	.025	.026	.028	.030

YOUNGSTOWN, OHIO LATITUDE = 41.2

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	27.09	21.14	16.09	12.83	10.62	9.04	7.86
VT2/DD	22.87	17.85	13.71	10.93	9.05	7.70	6.70
VT3/DD	19.81	15.46	11.90	9.48	7.85	6.68	5.82
ANNUAL DD	1688	2396	3256	4271	5423	6727	8209
PARAMETER A	.490	.519	.620	.717	.795	.864	.926
OFF SOUTH							
VTN/DD B1	.749	.749	.564	.564	.564	.564	.564
VTN/DD B2	-.054	-.054	-.093	-.093	-.093	-.093	-.093
A PARAM C1	-.085	-.155	.089	.039	.006	-.016	-.034
A PARAM C2	-.073	-.065	.049	.044	.041	.040	.040

OKLAHOMA CITY, OKLAHOMA LATITUDE = 35.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	120.62	84.75	62.65	48.67	39.38	32.97	28.32
VT2/DD	103.00	72.38	53.50	41.56	33.63	28.15	24.18
VT3/DD	89.48	62.87	46.48	36.10	29.21	24.46	21.01
ANNUAL DD	688	1111	1652	2322	3145	4120	5246
PARAMETER A	.475	.459	.451	.452	.469	.481	.483
OFF SOUTH							
VTN/DD B1	-.381	-.381	-.381	-.381	-.381	-.381	-.381
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	1.370	1.455	1.471	1.441	1.344	1.260	1.206
A PARAM C2	.056	.063	.068	.072	.077	.087	.102

TULSA, OKLAHOMA LATITUDE = 36.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	119.05	79.27	57.93	45.07	36.52	30.56	26.21
VT2/DD	101.74	67.75	49.50	38.52	31.21	26.11	22.40
VT3/DD	88.38	58.85	43.00	33.46	27.11	22.68	19.46
ANNUAL DD	658	1079	1618	2270	3050	3964	5022
PARAMETER A	.468	.495	.491	.474	.467	.468	.475
OFF SOUTH							
VTN/DD B1	.670	.670	.670	.670	.670	.670	.670
VTN/DD B2	-.109	-.109	-.109	-.109	-.109	-.109	-.109
A PARAM C1	-1.948	-1.880	-1.956	-2.078	-2.145	-2.171	-2.179
A PARAM C2	.050	.054	.063	.074	.085	.095	.106

ASTORIA, OREGON LATITUDE = 46.1

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	145.46	69.32	38.47	23.76	17.01	13.25	10.85
VT2/DD	124.27	59.22	32.86	20.30	14.54	11.32	9.27
VT3/DD	107.91	51.42	28.54	17.62	12.62	9.83	8.05
ANNUAL DD	192	529	1212	2271	3671	5330	7104
PARAMETER A	.712	.791	.847	.907	.975	1.023	1.035
OFF SOUTH							
VTN/DD B1	.207	.207	.207	.207	.207	.207	.207
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	-.202	-.212	-.259	-.280	-.297	-.339	-.403
A PARAM C2	.020	.028	.039	.044	.047	.050	.056

MEDFORD, OREGON LATITUDE = 42.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	54.15	30.50	20.33	15.15	12.07	10.03	8.58
VT2/DD	46.16	26.00	17.33	12.91	10.29	8.55	7.31
VT3/DD	40.06	22.56	15.04	11.21	8.93	7.42	6.35
ANNUAL DD	543	1120	1933	2954	4159	5516	6996
PARAMETER A	1.093	1.174	1.223	1.251	1.278	1.302	1.321
OFF SOUTH							
VTN/DD B1	-1.803	-1.803	-1.803	-1.803	-1.803	-1.803	-1.803
VTN/DD B2	-.094	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	.799	.697	.680	.654	.649	.646	.650
A PARAM C2	.005	.006	.008	.011	.013	.016	.019

NORTH BEND, OREGON — LATITUDE = 43.3

DUE SOUTH	TR40 (M=12)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	484.07	182.09	88.71	49.06	31.43	23.05	18.20
VT2/DD	413.66	155.63	75.82	41.92	26.86	19.70	15.56
VT3/DD	359.21	135.15	65.84	36.40	23.32	17.11	13.51
ANNUAL DD	83	293	791	1720	3120	4808	6613
PARAMETER A	.543	.722	.730	.831	.945	.961	.940
OFF SOUTH							
VTN/DD B1	.096	.163	.163	.096	.096	.096	.096
VTN/DD B2	-.105	-.106	-.106	-.105	-.105	-.105	-.105
A PARAM C1	-.033	-.454	-.757	-.701	-.712	-.823	-.955
A PARAM C2	.010	.031	.048	.050	.054	.065	.077

PORTLAND, OREGON — LATITUDE = 45.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	86.62	40.06	23.47	16.11	12.21	9.83	8.23
VT2/DD	73.55	34.02	19.92	13.68	10.37	8.35	6.98
VT3/DD	63.77	29.50	17.28	11.86	8.99	7.24	6.06
ANNUAL DD	251	639	1313	2255	3465	4910	6511
PARAMETER A	.787	.941	1.006	1.061	1.123	1.183	1.223
OFF SOUTH							
VTN/DD B1	-.831	-.831	-.831	-.831	-.831	-.831	-.831
VTN/DD B2	-.076	-.076	-.076	-.076	-.076	-.076	-.076
A PARAM C1	.941	.749	.713	.680	.626	.566	.522
A PARAM C2	-.015	-.010	-.008	-.005	-.002	.001	.004

REDMOND, OREGON — LATITUDE = 44.2

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	73.60	48.94	35.38	27.46	22.37	18.87	16.31
VT2/DD	63.08	41.94	30.32	23.53	19.17	16.17	13.98
VT3/DD	54.82	36.45	26.35	20.45	16.66	14.05	12.15
ANNUAL DD	1115	1862	2859	4065	5430	6922	8507
PARAMETER A	.796	.838	.845	.846	.843	.834	.820
OFF SOUTH							
VTN/DD B1	.254	.254	.254	.254	.254	.254	.254
VTN/DD B2	-.117	-.117	-.117	-.117	-.117	-.117	-.117
A PARAM C1	.500	.532	.571	.589	.594	.593	.594
A PARAM C2	.041	.047	.055	.064	.073	.083	.094

SALEM, OREGON — LATITUDE = 44.6

DUE SOUTH	TR40 (M= 1)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	130.26	61.05	31.30	19.75	14.35	11.26	9.27
VT2/DD	110.98	51.98	26.64	16.82	12.22	9.59	7.89
VT3/DD	96.31	45.09	23.12	14.59	10.60	8.32	6.84
ANNUAL DD	260	650	1391	2474	3790	5277	6886
PARAMETER A	.880	.953	1.049	1.116	1.161	1.193	1.213
OFF SOUTH							
VTN/DD B1	.045	-.528	-.528	-.528	-.528	-.528	-.528
VTN/DD B2	-.092	-.088	-.088	-.088	-.088	-.088	-.088
A PARAM C1	-.427	.400	.344	.321	.303	.288	.277
A PARAM C2	.013	.012	.013	.015	.017	.019	.022

ALLENTOWN, PENNSYLVANIA — LATITUDE = 40.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	43.98	32.90	25.64	20.44	16.97	14.48	12.63
VT2/DD	37.57	28.11	21.91	17.46	14.50	12.37	10.79
VT3/DD	32.63	24.41	19.02	15.17	12.59	10.75	9.37
ANNUAL DD	1357	2032	2807	3705	4759	5976	7373
PARAMETER A	.507	.505	.530	.590	.650	.704	.[illegible]53
OFF SOUTH							
VTN/DD B1	.280	.280	.571	.571	.571	.571	.571
VTN/DD B2	-.107	-.107	-.105	-.105	-.105	-.105	-.105
A PARAM C1	.479	.485	-.526	-.479	-.451	-.444	-.447
A PARAM C2	.047	.056	.058	.057	.057	.059	.061

ERIE, PENNSYLVANIA — LATITUDE = 42.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	27.59	20.77	16.15	12.87	10.68	9.09	7.92
VT2/DD	23.52	17.70	13.79	10.98	9.10	7.75	6.76
VT3/DD	20.41	15.36	11.97	9.53	7.90	6.73	5.86
ANNUAL DD	1530	2254	3111	4099	5234	6532	8014
PARAMETER A	.600	.613	.655	.727	.794	.860	.923
OFF SOUTH							
VTN/DD B1	.124	.124	.335	.335	.335	.335	.335
VTN/DD B2	-.094	-.094	-.100	-.100	-.100	-.100	-.100
A PARAM C1	-.518	-.529	-1.033	-.899	-.792	-.705	-.632
A PARAM C2	.033	.038	.058	.054	.051	.049	.047

HARRISBURG, PENNSYLVANIA — LATITUDE = 40.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	53.07	37.33	28.49	22.98	19.24	16.53	14.49
VT2/DD	45.32	31.88	24.34	19.63	16.43	14.12	12.38
VT3/DD	39.35	27.68	21.13	17.04	14.27	12.26	10.75
ANNUAL DD	985	1635	2415	3290	4274	5410	6734
PARAMETER A	.643	.652	.633	.613	.606	.622	.650
OFF SOUTH							
VTN/DD B1	-.502	-.502	-.502	-.502	-.502	-.502	-.502
VTN/DD B2	-.105	-.105	-.105	-.105	-.105	-.105	-.105
A PARAM C1	1.106	1.174	1.292	1.392	1.439	1.415	1.355
A PARAM C2	.032	.038	.048	.057	.065	.069	.073

PHILADELPHIA, PENNSYLVANIA — LATITUDE = 39.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	63.23	44.06	33.24	26.49	21.95	18.69	16.27
VT2/DD	54.00	37.63	28.38	22.62	18.74	15.96	13.89
VT3/DD	46.89	32.67	24.65	19.64	16.28	13.86	12.06
ANNUAL DD	865	1449	2171	3013	3982	5112	6412
PARAMETER A	.669	.648	.632	.621	.616	.625	.642
OFF SOUTH							
VTN/DD B1	.044	.044	.044	.044	.044	.044	.044
VTN/DD B2	-.104	-.104	-.104	-.104	-.104	-.104	-.104
A PARAM C1	-.302	-.231	-.167	-.114	-.068	-.030	-.006
A PARAM C2	.019	.027	.036	.046	.055	.063	.069

PITTSBURGH, PENNSYLVANIA — LATITUDE = 40.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	33.34	25.63	19.41	15.27	12.51	10.56	9.13
VT2/DD	28.45	21.86	16.54	13.01	10.66	9.00	7.78
VT3/DD	24.70	18.98	14.35	11.29	9.25	7.81	6.75
ANNUAL DD	1453	2118	2899	3812	4881	6120	7539
PARAMETER A	.574	.542	.602	.669	.734	.801	.866
OFF SOUTH							
VTN/DD B1	.549	.549	-.085	-.085	-.085	-.085	-.085
VTN/DD B2	-.100	-.100	-.093	-.093	-.093	-.093	-.093
A PARAM C1	-1.283	-1.386	.579	.509	.450	.396	.353
A PARAM C2	.059	.067	.040	.039	.037	.037	.037

WILKES-BARRE, PENNSYLVANIA — LATITUDE = 41.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	32.26	24.38	19.42	16.12	13.78	12.04	10.68
VT2/DD	27.49	20.78	16.55	13.74	11.75	10.26	9.11
VT3/DD	23.86	18.03	14.36	11.92	10.20	8.90	7.90
ANNUAL DD	1468	2180	3032	4019	5134	6407	7853
PARAMETER A	.614	.617	.636	.659	.688	.723	.756
OFF SOUTH							
VTN/DD B1	-.301	-.301	-.301	-.301	-.301	-.301	-.301
VTN/DD B2	-.094	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	.687	.690	.657	.615	.568	.519	.477
A PARAM C2	.015	.021	.026	.030	.034	.038	.042

PROVIDENCE, RHODE ISLAND				LATITUDE = 41.4			
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	52.85	37.14	28.06	22.18	18.26	15.47	13.42
VT2/DD	45.23	31.79	24.01	18.99	15.63	13.24	11.48
VT3/DD	39.29	27.62	20.86	16.49	13.57	11.50	9.98
ANNUAL DD	1218	1899	2733	3729	4864	6147	7594
PARAMETER A	.439	.508	.567	.621	.661	.698	.734
OFF SOUTH							
VTN/DD E1	.189	.189	.189	.189	.189	.189	.189
VTN/DD E2	-.113	-.113	-.113	-.113	-.113	-.113	-.113
A PARAM C1	-.601	-.519	-.481	-.450	-.431	-.408	-.382
A PARAM C2	.064	.069	.071	.073	.076	.078	.081

CHARLESTON, SOUTH CAROLINA				LATITUDE = 32.8			
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	466.60	245.59	141.31	89.85	61.32	44.69	34.59
VT2/DD	397.80	209.38	120.47	76.60	52.28	38.10	29.49
VT3/DD	345.43	181.81	104.61	66.51	45.40	33.08	25.61
ANNUAL DD	148	324	627	1065	1652	2406	3362
PARAMETER A	.578	.573	.556	.543	.554	.579	.604
OFF SOUTH							
VTN/DD E1	.270	.270	.270	.270	.270	.270	.270
VTN/DD E2	-.104	-.104	-.104	-.104	-.104	-.104	-.104
A PARAM C1	.220	.290	.340	.390	.417	.434	.439
A PARAM C2	.016	.023	.030	.038	.044	.050	.060

COLUMBIA, SOUTH CAROLINA				LATITUDE = 33.6			
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	215.30	120.76	78.23	56.20	42.80	33.81	27.57
VT2/DD	183.34	102.83	66.62	47.86	36.44	28.79	23.48
VT3/DD	159.15	89.27	57.83	41.55	31.64	24.99	20.38
ANNUAL DD	289	554	942	1461	2123	2942	3946
PARAMETER A	.819	.794	.750	.722	.705	.703	.714
OFF SOUTH							
VTN/DD E1	-.072	-.072	-.072	-.072	-.072	-.072	-.072
VTN/DD E2	-.096	-.096	-.096	-.096	-.096	-.096	-.096
A PARAM C1	.490	.547	.629	.659	.652	.613	.558
A PARAM C2	.007	.010	.013	.016	.020	.027	.035

GREENVILLE, SOUTH CAROLINA				LATITUDE = 34.5			
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 2)	(M= 2)	(M= 2)	(M= 2)	(M=12)	(M=12)	(M=12)
VT1/DD	186.96	119.62	82.97	60.06	44.18	34.36	28.01
VT2/DD	158.35	101.31	70.27	50.87	37.75	29.35	23.93
VT3/DD	137.28	87.83	60.92	44.10	32.79	25.50	20.78
ANNUAL DD	381	683	1110	1720	2518	3496	4659
PARAMETER A	.410	.414	.405	.430	.495	.546	.570
OFF SOUTH							
VTN/DD E1	-.114	-.114	-.114	-.114	-.107	-.107	-.107
VTN/DD E2	-.081	-.081	-.081	-.081	-.108	-.108	-.108
A PARAM C1	.513	.518	.557	.541	.469	.404	.365
A PARAM C2	-.060	-.054	-.050	-.039	.075	.083	.096

HURON, SOUTH DAKOTA				LATITUDE = 44.2			
	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	19.58	16.31	13.95	12.18	10.81	9.72	8.82
VT2/DD	16.76	13.96	11.94	10.43	9.26	8.32	7.55
VT3/DD	14.57	12.13	10.38	9.06	8.04	7.23	6.56
ANNUAL DD	3149	4011	4985	6077	7273	8588	10028
PARAMETER A	.739	.802	.856	.904	.943	.977	1.007
OFF SOUTH							
VTN/DD E1	-.200	-.200	-.200	-.200	-.200	-.200	-.200
VTN/DD E2	-.112	-.112	-.112	-.112	-.112	-.112	-.112
A PARAM C1	.015	.041	.066	.090	.113	.134	.152
A PARAM C2	.021	.021	.023	.025	.027	.030	.033

PIERRE, SOUTH DAKOTA — LATITUDE = 44.2

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	32.52	26.96	23.03	20.09	17.82	16.01	14.53
VT2/DD	27.88	23.12	19.74	17.22	15.27	13.72	12.46
VT3/DD	24.23	20.09	17.15	14.97	13.27	11.93	10.83
ANNUAL DD	2496	3299	4212	5243	6395	7667	9072
PARAMETER A	.578	.593	.607	.625	.645	.664	.682
OFF SOUTH							
VTN/DD B1	.240	.240	.240	.240	.240	.240	.240
VTN/DD B2	-.119	-.119	-.119	-.119	-.119	-.119	-.119
A PARAM C1	.019	.040	.056	.065	.071	.074	.074
A PARAM C2	.036	.042	.048	.053	.059	.066	.072

RAPID CITY, SOUTH DAKOTA — LATITUDE = 44.0

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	47.93	37.94	30.98	25.88	22.21	19.45	17.29
VT2/DD	41.10	32.53	26.60	22.22	19.07	16.70	14.84
VT3/DD	35.72	28.27	23.12	19.32	16.58	14.51	12.91
ANNUAL DD	2159	2956	3903	4980	6185	7529	9009
PARAMETER A	.527	.527	.545	.573	.596	.616	.630
OFF SOUTH							
VTN/DD B1	.249	.249	.837	.837	.837	.837	.837
VTN/DD B2	-.120	-.120	-.124	-.124	-.124	-.124	-.124
A PARAM C1	.786	.805	-1.310	-1.228	-1.169	-1.122	-1.088
A PARAM C2	.050	.059	.082	.088	.094	.102	.110

SIOUX FALLS, SOUTH DAKOTA — LATITUDE = 43.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	29.73	24.86	21.36	18.72	16.66	15.01	13.66
VT2/DD	25.48	21.30	18.30	16.04	14.27	12.86	11.70
VT3/DD	22.14	18.51	15.90	13.94	12.41	11.18	10.17
ANNUAL DD	2661	3500	4439	5487	6644	7924	9349
PARAMETER A	.688	.690	.698	.713	.724	.734	.744
OFF SOUTH							
VTN/DD B1	-.610	-.610	-.610	-.610	-.610	-.610	-.610
VTN/DD B2	-.117	-.117	-.117	-.117	-.117	-.117	-.117
A PARAM C1	1.776	1.869	1.905	1.903	1.898	1.888	1.866
A PARAM C2	.027	.032	.037	.042	.049	.056	.063

CHATTANOOGA, TENNESSEE — LATITUDE = 35.0

DUE SOUTH	TR40 (M= 2)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	138.13	86.06	55.92	40.50	31.19	25.08	20.91
VT2/DD	116.79	73.43	47.72	34.56	26.61	21.40	17.84
VT3/DD	101.20	63.75	41.43	30.01	23.11	18.58	15.49
ANNUAL DD	510	925	1483	2154	2949	3895	5035
PARAMETER A	.454	.433	.508	.545	.573	.601	.637
OFF SOUTH							
VTN/DD B1	-.149	-.024	-.024	-.024	-.024	-.024	-.024
VTN/DD B2	-.071	-.102	-.102	-.102	-.102	-.102	-.102
A PARAM C1	.399	-.111	-.169	-.219	-.259	-.293	-.319
A PARAM C2	-.054	.073	.063	.063	.066	.070	.074

KNOXVILLE, TENNESSEE — LATITUDE = 35.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	94.64	66.94	49.39	38.02	30.23	24.91	21.13
VT2/DD	80.69	57.07	42.11	32.41	25.77	21.24	18.02
VT3/DD	70.05	49.55	36.56	28.14	22.38	18.44	15.64
ANNUAL DD	584	974	1515	2196	3028	4004	5162
PARAMETER A	.676	.614	.577	.550	.541	.539	.559
OFF SOUTH							
VTN/DD B1	-.141	-.141	-.141	-.141	-.141	-.141	-.141
VTN/DD B2	-.100	-.100	-.100	-.100	-.100	-.100	-.100
A PARAM C1	.085	-.000	-.059	-.109	-.145	-.172	-.185
A PARAM C2	.020	.028	.037	.047	.055	.064	.073

MEMPHIS, TENNESSEE LATITUDE = 35.0

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	186.42	104.84	68.64	49.17	37.72	30.23	25.08
VT2/DD	158.21	89.31	58.47	41.89	32.13	25.75	21.36
VT3/DD	137.86	77.53	50.76	36.36	27.89	22.36	18.54
ANNUAL DD	372	700	1162	1767	2493	3358	4371
PARAMETER A	.558	.538	.523	.526	.533	.551	.567
OFF SOUTH							
VTN/DD B1	-.057	-.057	-.057	-.057	-.057	-.057	-.057
VTN/DD B2	-.097	-.097	-.097	-.097	-.097	-.097	-.097
A PARAM C1	.142	.134	.144	.159	.174	.190	.208
A PARAM C2	.024	.029	.034	.036	.040	.044	.051

NASHVILLE, TENNESSEE LATITUDE = 36.1

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	126.16	78.15	53.54	39.31	30.46	24.35	20.28
VT2/DD	107.62	66.78	45.75	33.60	25.98	20.78	17.30
VT3/DD	93.43	58.00	39.74	29.18	22.56	18.04	15.02
ANNUAL DD	500	874	1374	2018	2803	3742	4880
PARAMETER A	.411	.483	.533	.560	.579	.605	.627
OFF SOUTH							
VTN/DD B1	-.099	.321	.321	.321	-.099	-.099	-.099
VTN/DD B2	-.103	-.109	-.109	-.109	-.103	-.103	-.103
A PARAM C1	1.737	-.271	-.387	-.483	.725	.620	.533
A PARAM C2	.037	.064	.065	.069	.054	.059	.066

ABILENE, TEXAS LATITUDE = 32.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	238.34	148.85	102.07	74.46	57.27	45.97	38.15
VT2/DD	203.63	127.17	87.21	63.61	48.93	39.27	32.59
VT3/DD	176.92	110.49	75.77	55.27	42.51	34.12	28.32
ANNUAL DD	326	610	1024	1562	2224	3032	3989
PARAMETER A	.682	.648	.586	.543	.527	.521	.511
OFF SOUTH							
VTN/DD B1	-.446	-.446	-.446	-.446	-.446	-.446	-.446
VTN/DD B2	-.109	-.109	-.109	-.109	-.109	-.109	-.109
A PARAM C1	.019	.009	.009	.014	.021	.033	.063
A PARAM C2	.030	.041	.054	.067	.077	.089	.107

AMARILLO, TEXAS LATITUDE = 35.1

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 2)	(M= 2)	(M= 2)	(M= 2)	(M= 2)	(M= 2)	(M= 2)
VT1/DD	170.78	113.85	81.91	62.65	50.00	41.28	35.09
VT2/DD	144.84	96.38	69.47	53.13	42.41	35.01	29.76
VT3/DD	125.58	83.57	60.23	46.07	36.77	30.36	25.80
ANNUAL DD	829	1333	1976	2756	3671	4732	5973
PARAMETER A	.426	.429	.444	.455	.461	.469	.477
OFF SOUTH							
VTN/DD B1	-.077	-.077	-.077	-.077	-.077	-.077	-.077
VTN/DD B2	-.086	-.086	-.086	-.086	-.086	-.086	-.086
A PARAM C1	-.139	-.089	-.042	-.000	.039	.072	.100
A PARAM C2	-.048	-.037	-.024	-.011	.005	.023	.042

AUSTIN, TEXAS LATITUDE = 30.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	1210.9	446.81	210.02	121.91	82.15	60.25	46.75
VT2/DD	1031.1	380.46	178.83	103.80	69.95	51.31	39.80
VT3/DD	895.38	330.36	155.28	90.14	60.74	44.55	34.56
ANNUAL DD	73	215	484	870	1378	2026	2847
PARAMETER A	.498	.438	.412	.413	.415	.423	.428
OFF SOUTH							
VTN/DD B1	.053	.053	.053	.053	.053	.053	.053
VTN/DD B2	-.098	-.098	-.098	-.098	-.098	-.098	-.098
A PARAM C1	-1.724	-2.001	-2.109	-2.075	-2.019	-1.943	-1.901
A PARAM C2	.065	.068	.068	.068	.073	.081	.096

BROWNSVILLE, TEXAS — LATITUDE = 25.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	1434.3	562.04	282.25	161.86	102.78	68.42
VT2/DD	NA	1216.1	476.53	239.31	137.24	87.14	58.01
VT3/DD	NA	1055.2	413.52	207.66	119.09	75.62	50.34
ANNUAL DD	NA	35	108	247	466	798	1295
PARAMETER A	NA	.319	.489	.458	.424	.440	.494
OFF SOUTH							
VTN/DD B1	NA	.477	.477	.477	.477	.477	.477
VTN/DD B2	NA	-.085	-.085	-.085	-.085	-.085	-.085
A PARAM C1	NA	-.673	-.337	-.206	-.135	-.034	.029
A PARAM C2	NA	.021	.021	.033	.047	.058	.060

CORPUS CHRISTI, TEXAS — LATITUDE = 27.5

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	2074.7	775.63	351.59	188.98	114.52	78.14	56.95
VT2/DD	1765.6	660.09	299.21	160.83	97.46	66.50	48.47
VT3/DD	1533.1	573.14	259.80	139.64	84.62	57.74	42.08
ANNUAL DD	28	81	185	364	648	1065	1647
PARAMETER A	.325	.401	.523	.573	.591	.553	.522
OFF SOUTH							
VTN/DD B1	-.542	-.542	-.542	-.542	-.542	-.542	-.542
VTN/DD B2	-.098	-.098	-.098	-.098	-.098	-.098	-.098
A PARAM C1	1.746	1.316	.904	.760	.677	.681	.666
A PARAM C2	.034	.037	.035	.041	.049	.063	.079

DEL RIO, TEXAS — LATITUDE = 29.2

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	976.52	463.19	249.37	147.39	96.63	68.[illegible]	52.23
VT2/DD	823.24	390.48	210.23	124.26	81.47	58.[illegible]1	44.03
VT3/DD	712.82	338.11	182.03	107.59	70.54	50.31	38.13
ANNUAL DD	66	168	364	672	1095	1656	2402
PARAMETER A	.452	.486	.430	.450	.479	.502	.526
OFF SOUTH							
VTN/DD B1	-1.264	-1.264	-1.264	-1.264	-1.264	-1.264	-1.264
VTN/DD B2	-.069	-.069	-.069	-.069	-.069	-.069	-.069
A PARAM C1	1.851	1.618	1.812	1.681	1.553	1.468	1.394
A PARAM C2	-.072	-.075	-.089	-.083	-.071	-.056	-.038

EL PASO, TEXAS — LATITUDE = 31.8

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	431.50	247.38	158.85	109.62	80.66	62.30	50.41
VT2/DD	368.00	210.98	135.47	93.49	68.79	53.13	42.99
VT3/DD	319.65	183.25	117.67	81.20	59.75	46.15	37.34
ANNUAL DD	222	458	825	1334	2001	2826	3808
PARAMETER A	.551	.582	.560	.558	.545	.532	.520
OFF SOUTH							
VTN/DD B1	-.165	-.165	-.165	-.165	-.165	-.165	-.165
VTN/DD B2	-.104	-.104	-.104	-.104	-.104	-.104	-.104
A PARAM C1	.245	.365	.557	.699	.844	.978	1.118
A PARAM C2	.007	.015	.025	.035	.047	.063	.083

FORT WORTH, TEXAS — LATITUDE = 32.8

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	280.94	163.65	103.78	71.97	53.08	41.24	33.52
VT2/DD	239.55	139.54	88.49	61.37	45.26	35.17	28.58
VT3/DD	208.03	121.18	76.85	53.29	39.31	30.54	24.82
ANNUAL DD	229	449	793	1257	1870	2643	3598
PARAME ER A	.603	.594	.593	.597	.610	.615	.612
OFF SOUTH							
VTN/DD B1	-.392	-.392	-.392	-.392	-.392	-.392	-.392
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	.228	.262	.265	.257	.237	.222	.212
A PARAM C2	.025	.028	.031	.036	.041	.049	.064

HOUSTON, TEXAS LATITUDE = 29.6

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	718.24	353.23	190.70	112.19	74.71	53.36	40.44
VT2/DD	611.12	300.55	162.26	95.46	63.57	45.40	34.41
VT3/DD	530.48	260.89	140.85	82.86	55.18	39.41	29.87
ANNUAL DD	52	146	314	589	1001	1580	2349
PARAMETER A	.646	.453	.404	.474	.519	.556	.564
OFF SOUTH							
VTN/DD B1	-.689	-.689	-.689	-.689	-.689	-.689	-.689
VTN/DD B2	-.094	-.094	-.094	-.094	-.094	-.094	-.094
A PARAM C1	.608	1.428	1.709	1.423	1.270	1.152	1.103
A PARAM C2	.020	.044	.056	.052	.057	.064	.075

KINGSVILLE, TEXAS LATITUDE = 27.3

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	1126.3	412.97	207.39	121.11	80.12	57.07
VT2/DD	NA	955.39	350.29	175.92	102.73	67.96	48.41
VT3/DD	NA	829.06	303.97	152.65	89.14	58.97	42.01
ANNUAL DD	NA	53	158	351	649	1066	1649
PARAMETER A	NA	.621	.695	.643	.609	.578	.562
OFF SOUTH							
VTN/DD B1	NA	-.980	-.980	-.980	-.980	-.980	-.980
VTN/DD B2	NA	-.084	-.084	-.084	-.084	-.084	-.084
A PARAM C1	NA	1.611	1.390	1.606	1.776	1.921	1.997
A PARAM C2	NA	.005	.014	.023	.028	.033	.039

LAREDO, TEXAS LATITUDE = 27.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	NA	1580.5	597.22	281.12	154.40	96.00	66.69
VT2/DD	NA	1345.2	508.33	239.28	131.05	81.48	56.61
VT3/DD	NA	1168.2	441.43	207.79	113.74	70.72	49.13
ANNUAL DD	NA	45	144	339	643	1082	1676
PARAMETER A	NA	.393	.391	.371	.382	.410	.433
OFF SOUTH							
VTN/DD B1	NA	-1.272	-1.272	-1.272	-.119	-.119	-.119
VTN/DD B2	NA	-.097	-.097	-.097	-.089	-.089	-.089
A PARAM C1	NA	1.759	2.173	2.703	-2.682	-2.371	-2.193
A PARAM C2	NA	.030	.045	.061	.022	.034	.046

LUBBOCK, TEXAS LATITUDE = 33.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	198.69	124.76	87.90	66.86	53.32	44.19	37.70
VT2/DD	169.73	106.57	75.09	57.12	45.55	37.75	32.20
VT3/DD	147.48	92.60	65.24	49.63	39.57	32.80	27.98
ANNUAL DD	608	1026	1568	2242	3055	4000	5125
PARAMETER A	.480	.517	.540	.544	.540	.530	.520
OFF SOUTH							
VTN/DD B1	.369	.369	.369	.369	.369	.369	.369
VTN/DD B2	-.111	-.111	-.111	-.111	-.111	-.111	-.111
A PARAM C1	-1.170	-1.090	-1.070	-1.080	-1.093	-1.112	-1.137
A PARAM C2	.055	.055	.057	.064	.076	.091	.112

LUFKIN, TEXAS LATITUDE = 31.1

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	372.79	201.06	128.05	87.27	63.88	49.33	39.17
VT2/DD	317.07	171.01	108.91	74.22	54.33	41.95	33.31
VT3/DD	275.22	148.44	94.54	64.43	47.16	36.42	28.92
ANNUAL DD	166	329	580	952	1457	2095	2929
PARAMETER A	.527	.594	.600	.583	.543	.524	.530
OFF SOUTH							
VTN/DD B1	-.746	-.746	-.746	-.746	-.746	-.746	-.746
VTN/DD B2	-.092	-.092	-.092	-.092	-.092	-.092	-.092
A PARAM C1	-.459	-.306	-.165	-.042	.062	.152	.222
A PARAM C2	.001	.006	.016	.027	.037	.047	.060

MIDLAND-ODESSA, TEXAS LATITUDE = 31.6

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	415.04	212.73	131.11	90.69	68.06	53.86	44.46
VT2/DD	354.13	181.51	111.87	77.38	58.07	45.98	37.94
VT3/DD	307.65	157.69	97.19	67.23	50.45	39.94	32.96
ANNUAL DD	255	542	953	1491	2148	2953	3935
PARAMETER A	.510	.565	.577	.568	.559	.554	.557
OFF SOUTH							
VTN/DD B1	.504	.504	.504	.504	.504	.504	.504
VTN/DD B2	-.107	-.107	-.107	-.107	-.107	-.107	-.107
A PARAM C1	-1.322	-1.258	-1.310	-1.404	-1.496	-1.575	-1.636
A PARAM C2	.027	.031	.036	.046	.057	.069	.084

PORT ARTHUR, TEXAS LATITUDE = 29.6

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	1322.8	529.37	268.89	146.63	86.41	57.57	41.57
VT2/DD	1127.1	451.08	229.12	124.54	73.40	48.89	35.31
VT3/DD	978.80	391.70	198.96	108.08	63.70	42.43	30.64
ANNUAL DD	44	129	300	595	1025	1628	2439
PARAMETER A	.545	.455	.350	.366	.470	.536	.578
OFF SOUTH							
VTN/DD B1	-.346	-.346	-.346	-.829	-.829	-.829	-.829
VTN/DD B2	-.101	-.101	-.101	-.089	-.089	-.089	-.089
A PARAM C1	.011	-.147	-.057	2.358	1.884	1.710	1.634
A PARAM C2	.052	.067	.096	.031	.029	.035	.045

SAN ANGELO, TEXAS LATITUDE = 31.2

DUE SOUTH	TR40 (M=12)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	442.92	245.39	148.57	98.36	71.09	54.60	43.98
VT2/DD	378.36	209.16	126.64	83.84	60.59	46.54	37.48
VT3/DD	328.74	181.66	109.99	72.82	52.63	40.42	32.56
ANNUAL DD	240	464	784	1229	1800	2512	3387
PARAMETER A	.363	.382	.443	.473	.486	.493	.503
OFF SOUTH							
VTN/DD B1	.222	-.195	-.195	-.195	-.195	-.195	-.195
VTN/DD B2	-.110	-.101	-.101	-.101	-.101	-.101	-.101
A PARAM C1	-1.757	.316	.253	.231	.208	.166	.110
A PARAM C2	.082	.044	.048	.053	.062	.071	.084

SAN ANTONIO, TEXAS LATITUDE = 29.3

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	686.93	341.56	198.18	124.56	85.52	63.13	48.81
VT2/DD	585.26	291.01	168.85	106.13	72.86	53.79	41.58
VT3/DD	508.25	252.72	146.63	92.16	63.28	46.71	36.11
ANNUAL DD	78	200	425	771	1242	1844	2609
PARAMETER A	.692	.695	.570	.494	.470	.459	.451
OFF SOUTH							
VTN/DD B1	-1.157	-1.157	-1.157	-1.157	-1.157	-1.157	-1.157
VTN/DD B2	-.099	-.099	-.099	-.099	-.099	-.099	-.099
A PARAM C1	.653	.861	1.255	1.529	1.625	1.672	1.703
A PARAM C2	.008	.022	.042	.057	.070	.085	.104

SHERMAN, TEXAS LATITUDE = 33.4

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	249.95	137.53	87.51	61.86	47.15	37.77	31.22
VT2/DD	213.25	117.33	74.66	52.78	40.23	32.22	26.64
VT3/DD	185.20	101.90	64.84	45.84	34.94	27.98	23.13
ANNUAL DD	222	477	872	1407	2091	2920	3902
PARAMETER A	.727	.693	.648	.598	.570	.549	.538
OFF SOUTH							
VTN/DD B1	.528	.528	.528	.528	.528	.528	.528
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	-.632	-.893	-1.123	-1.314	-1.439	-1.552	-1.650
A PARAM C2	.025	.032	.039	.046	.053	.063	.078

WACO, TEXAS LATITUDE = 31.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	325.18	185.94	118.18	79.89	57.64	43.87	35.12
VT2/DD	276.73	158.24	100.58	67.99	49.05	37.33	29.89
VT3/DD	240.25	137.38	87.32	59.03	42.58	32.41	25.95
ANNUAL DD	196	399	714	1157	1729	2443	3300
PARAMETER A	.664	.610	.551	.552	.556	.570	.572
OFF SOUTH							
VTN/DD B1	-.835	-.835	-.835	-.835	-.835	-.835	-.835
VTN/DD B2	-.093	-.093	-.093	-.093	-.093	-.093	-.093
A PARAM C1	.939	1.063	1.215	1.220	1.208	1.166	1.145
A PARAM C2	.022	.024	.028	.031	.035	.040	.048

WICHITA FALLS, TEXAS LATITUDE = 33.6

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	204.85	124.75	85.28	63.12	49.15	39.78	33.20
VT2/DD	174.72	106.40	72.74	53.84	41.92	33.93	28.32
VT3/DD	151.74	92.41	63.17	46.76	36.41	29.47	24.59
ANNUAL DD	463	786	1225	1793	2508	3378	4402
PARAMETER A	.410	.445	.459	.455	.477	.501	.515
OFF SOUTH							
VTN/DD B1	-.055	-.055	-.055	-.055	-.055	-.055	-.055
VTN/DD B2	-.103	-.103	-.103	-.103	-.103	-.103	-.103
A PARAM C1	.232	.179	.148	.124	.101	.076	.049
A PARAM C2	.040	.043	.047	.053	.058	.067	.081

BRYCE CANYON, UTAH LATITUDE = 37.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	68.05	54.50	45.36	38.84	33.95	30.16	27.13
VT2/DD	58.30	46.69	38.86	33.27	29.09	25.84	23.24
VT3/DD	50.67	40.58	33.78	28.92	25.28	22.46	20.20
ANNUAL DD	2929	3969	5147	6450	7884	9431	11088
PARAMETER A	.492	.473	.452	.426	.394	.354	.307
OFF SOUTH							
VTN/DD B1	.048	.048	.048	.048	.048	.048	.048
VTN/DD B2	-.120	-.120	-.120	-.120	-.120	-.120	-.120
A PARAM C1	.712	.797	.883	.988	1.135	1.345	1.655
A PARAM C2	.123	.151	.181	.218	.266	.333	.427

CEDAR CITY, UTAH LATITUDE = 37.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	102.65	73.60	56.04	44.86	37.38	32.03	28.02
VT2/DD	88.00	63.09	48.04	38.46	32.04	27.46	24.02
VT3/DD	76.50	54.84	41.76	33.43	27.85	23.87	20.88
ANNUAL DD	1364	2055	2890	3865	4984	6258	7679
PARAMETER A	.505	.516	.521	.520	.517	.517	.515
OFF SOUTH							
VTN/DD B1	.447	.447	.447	.447	.447	.447	.447
VTN/DD B2	-.122	-.122	-.122	-.122	-.122	-.122	-.122
A PARAM C1	-1.109	-1.029	-.980	-.957	-.949	-.933	-.923
A PARAM C2	.091	.102	.116	.133	.151	.167	.187

SALT LAKE CITY, UTAH LATITUDE = 40.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	59.92	44.05	34.47	28.24	23.91	20.73	18.30
VT2/DD	51.27	37.69	29.50	24.16	20.46	17.74	15.65
VT3/DD	44.54	32.74	25.62	20.99	17.77	15.41	13.60
ANNUAL DD	1263	1957	2812	3814	4969	6251	7646
PARAMETER A	.731	.775	.804	.822	.833	.837	.835
OFF SOUTH							
VTN/DD B1	-.020	-.020	-.020	-.020	-.020	-.020	-.020
VTN/DD B2	-.112	-.112	-.112	-.112	-.112	-.112	-.112
A PARAM C1	-.067	-.050	-.037	-.025	-.012	-.000	.011
A PARAM C2	.002	.010	.018	.027	.037	.047	.057

BURLINGTON, VERMONT LATITUDE = 44.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	24.84	19.88	16.35	13.84	11.93	10.45	9.30
VT2/DD	21.25	17.01	13.99	11.84	10.21	8.94	7.95
VT3/DD	18.46	14.77	12.15	10.29	8.87	7.77	6.91
ANNUAL DD	2430	3260	4214	5310	6552	7945	9483
PARAMETER A	.563	.620	.677	.734	.789	.838	.880
OFF SOUTH							
VTN/DD B1	-.042	-.184	-.184	-.184	-.184	-.184	-.184
VTN/DD B2	-.110	-.109	-.109	-.109	-.109	-.109	-.109
A PARAM C1	.136	.590	.589	.578	.563	.547	.532
A PARAM C2	.055	.053	.052	.052	.052	.052	.054

NORFOLK, VIRGINIA LATITUDE = 36.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 2)	(M= 2)	(M= 2)	(M= 2)	(M= 2)
VT1/DD	172.33	104.69	62.77	42.85	32.41	26.07	21.80
VT2/DD	147.25	89.45	53.13	36.27	27.44	22.06	18.45
VT3/DD	127.90	77.70	46.05	31.43	23.78	19.12	15.99
ANNUAL DD	368	764	1302	1971	2778	3736	4875
PARAMETER A	.509	.346	.463	.571	.637	.670	.694
OFF SOUTH							
VTN/DD B1	-.460	-.460	.990	.990	.990	.990	.990
VTN/DD B2	-.110	-.110	-.073	-.073	-.073	-.073	-.073
A PARAM C1	1.600	2.917	-3.033	-2.389	-2.124	-2.033	-1.977
A PARAM C2	.045	.090	-.071	-.051	-.040	-.031	-.022

RICHMOND, VIRGINIA LATITUDE = 37.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	114.44	72.05	50.92	38.65	30.99	25.80	22.05
VT2/DD	97.70	61.51	43.47	32.99	26.46	22.02	18.83
VT3/DD	84.84	53.42	37.75	28.65	22.98	19.13	16.35
ANNUAL DD	595	1023	1587	2299	3154	4165	5354
PARAMETER A	.534	.603	.623	.622	.613	.610	.613
OFF SOUTH							
VTN/DD B1	-.299	-.299	-.299	-.299	-.299	-.299	-.299
VTN/DD B2	-.105	-.105	-.105	-.105	-.105	-.105	-.105
A PARAM C1	1.582	1.359	1.291	1.268	1.256	1.221	1.166
A PARAM C2	.032	.032	.036	.043	.051	.059	.070

ROANOKE, VIRGINIA LATITUDE = 37.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	111.01	69.69	49.08	37.46	30.12	25.07	21.44
VT2/DD	94.67	59.43	41.85	31.94	25.68	21.38	18.28
VT3/DD	82.19	51.60	36.34	27.74	22.30	18.56	15.87
ANNUAL DD	662	1118	1722	2484	3387	4451	5708
PARAMETER A	.556	.603	.617	.623	.621	.626	.640
OFF SOUTH							
VTN/DD B1	.382	.382	.382	.382	.382	.382	.382
VTN/DD B2	-.099	-.099	-.099	-.099	-.099	-.099	-.099
A PARAM C1	-.949	-.976	-1.042	-1.116	-1.207	-1.270	-1.298
A PARAM C2	.024	.025	.029	.034	.041	.048	.056

OLYMPIA, WASHINGTON LATITUDE = 46.6

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	82.21	37.47	21.07	14.33	10.86	8.74	7.31
VT2/DD	70.08	31.91	17.94	12.21	9.25	7.44	6.23
VT3/DD	60.82	27.69	15.57	10.59	8.02	6.46	5.40
ANNUAL DD	416	939	1793	2929	4301	5851	7507
PARAMETER A	.869	.970	1.083	1.152	1.208	1.247	1.270
OFF SOUTH							
VTN/DD B1	.359	.162	.162	.162	.162	.162	.162
VTN/DD B2	-.094	-.089	-.089	-.089	-.089	-.089	-.089
A PARAM C1	-.307	-.028	-.061	-.091	-.119	-.147	-.173
A PARAM C2	.015	.008	.009	.011	.013	.015	.018

SEATTLE, WASHINGTON — LATITUDE = 47.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	81.35	40.92	24.10	15.96	11.91	9.50	7.90
VT2/DD	69.47	34.83	20.51	13.63	10.17	8.11	6.74
VT3/DD	60.32	30.22	17.80	11.83	8.83	7.04	5.86
ANNUAL DD	284	732	1500	2585	3957	5531	7223
PARAMETER A	.782	.890	.954	1.039	1.121	1.179	1.212
OFF SOUTH							
VTN/DD B1	.324	.460	.460	.324	.324	.324	.324
VTN/DD B2	-.099	-.086	-.086	-.099	-.099	-.099	-.099
A PARAM C1	-.320	-.568	-.565	-.343	-.319	.317	-.331
A PARAM C2	.024	.003	.007	.029	.029	.030	.032

SPOKANE, WASHINGTON — LATITUDE = 47.4

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	24.35	17.29	13.38	10.91	9.21	7.97	7.02
VT2/DD	20.81	14.78	11.43	9.32	7.87	6.81	6.00
VT3/DD	18.08	12.83	9.93	8.10	6.84	5.92	5.21
ANNUAL DD	1338	2135	3113	4247	5540	6982	8536
PARAMETER A	.983	1.048	1.107	1.158	1.209	1.255	1.290
OFF SOUTH							
VTN/DD B1	.317	.317	.317	.317	.317	.317	.317
VTN/DD B2	-.104	-.104	-.104	-.104	-.104	-.104	-.104
A PARAM C1	.063	.034	.021	.017	.015	.014	.013
A PARAM C2	.006	.007	.009	.011	.012	.014	.016

WHIDBEY ISLAND, WASHINGTON — LATITUDE = 48.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)
VT1/DD	96.96	42.80	25.13	17.33	12.98	9.59	7.60
VT2/DD	82.61	36.47	21.42	14.77	11.03	8.14	6.45
VT3/DD	71.89	31.64	18.58	12.82	9.57	7.06	5.60
ANNUAL DD	221	557	1231	2296	3739	5424	7203
PARAMETER A	1.099	1.152	1.123	1.116	1.170	1.289	1.350
OFF SOUTH							
VTN/DD B1	.238	.238	.238	.238	.962	.962	.962
VTN/DD B2	-.090	-.090	-.090	-.090	-.077	-.077	-.077
A PARAM C1	-.260	-.210	-.270	-.326	-1.161	-1.025	-.973
A PARAM C2	.003	.005	.008	.013	.001	.004	.007

YAKIMA, WASHINGTON — LATITUDE = 46.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M= 1)
VT1/DD	30.46	22.45	17.46	14.20	11.95	10.31	9.07
VT2/DD	26.02	19.17	14.91	12.13	10.20	8.81	7.74
VT3/DD	22.59	16.65	12.95	10.53	8.86	7.65	6.72
ANNUAL DD	1070	1737	2601	3657	4863	6219	7699
PARAMETER A	.886	.952	1.011	1.059	1.098	1.134	1.162
OFF SOUTH							
VTN/DD B1	-.009	-.009	-.009	-.009	-.009	-.009	-.009
VTN/DD B2	-.102	-.102	-.102	-.102	-.102	-.102	-.102
A PARAM C1	-.114	-.047	.005	.045	.074	.096	.113
A PARAM C2	-.001	.001	.004	.007	.009	.012	.015

CHARLESTON, WEST VIRGINIA — LATITUDE = 38.2

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)
VT1/DD	53.22	39.44	30.41	24.15	19.52	15.86	13.31
VT2/DD	45.34	33.61	25.91	20.58	16.62	13.51	11.33
VT3/DD	39.36	29.17	22.49	17.86	14.43	11.72	9.84
ANNUAL DD	907	1406	2034	2822	3768	4875	6159
PARAMETER A	.570	.575	.575	.592	.630	.698	.759
OFF SOUTH							
VTN/DD B1	-.016	-.016	-.016	-.016	-.116	-.116	-.116
VTN/DD B2	-.095	-.095	-.095	-.095	-.091	-.091	-.091
A PARAM C1	-.136	-.202	-.259	-.301	-.070	-.092	-.105
A PARAM C2	.031	.038	.045	.050	.043	.043	.045

EAU CLAIRE, WISCONSIN LATITUDE = 44.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	18.24	14.75	12.37	10.64	9.34	8.32	7.50
VT2/DD	15.59	12.61	10.57	9.10	7.98	7.11	6.41
VT3/DD	13.54	10.95	9.18	7.90	6.93	6.17	5.57
ANNUAL DD	2982	3847	4813	5883	7068	8390	9858
PARAMETER A	.734	.806	.870	.925	.975	1.022	1.064
OFF SOUTH							
VTN/DD B1	.157	.157	.157	.157	.157	.157	.157
VTN/DD B2	-.106	-.106	-.106	-.106	-.106	-.106	-.106
A PARAM C1	.044	.119	.161	.185	.196	.198	.197
A PARAM C2	.013	.014	.016	.017	.019	.020	.022

GREEN BAY, WISCONSIN LATITUDE = 44.3

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	24.59	20.50	17.10	14.59	12.71	11.26	10.11
VT2/DD	21.07	17.57	14.65	12.50	10.89	9.65	8.66
VT3/DD	18.30	15.26	12.73	10.86	9.46	8.38	7.52
ANNUAL DD	2564	3420	4394	5502	6757	8145	9677
PARAMETER A	.623	.641	.697	.754	.805	.846	.879
OFF SOUTH							
VTN/DD B1	-.145	-.145	1.139	1.139	1.139	1.139	1.139
VTN/DD B2	-.116	-.116	-.114	-.114	-.114	-.114	-.114
A PARAM C1	1.593	1.553	-1.848	-1.680	-1.555	-1.468	-1.405
A PARAM C2	.036	.042	.040	.042	.044	.047	.051

LA CROSSE, WISCONSIN LATITUDE = 43.5

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	30.83	23.77	19.04	15.88	13.62	11.92	10.60
VT2/DD	26.41	20.35	16.30	13.59	11.66	10.21	9.07
VT3/DD	22.94	17.68	14.16	11.81	10.13	8.87	7.88
ANNUAL DD	2236	3036	3938	4959	6117	7416	8859
PARAMETER A	.505	.559	.629	.693	.751	.800	.843
OFF SOUTH							
VTN/DD B1	-.773	-.275	-.275	-.275	-.275	-.275	-.275
VTN/DD B2	-.116	-.113	-.113	-.113	-.113	-.113	-.113
A PARAM C1	1.324	-.360	-.220	-.131	-.070	-.025	.011
A PARAM C2	.055	.042	.041	.041	.042	.045	.047

MADISON, WISCONSIN LATITUDE = 43.1

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M= 1)	(M= 1)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	29.88	24.62	20.38	16.95	14.50	12.68	11.26
VT2/DD	25.57	21.07	17.46	14.52	12.43	10.86	9.65
VT3/DD	22.21	18.30	15.17	12.62	10.80	9.44	8.38
ANNUAL DD	2359	3168	4074	5103	6261	7567	9029
PARAMETER A	.588	.567	.596	.663	.720	.771	.815
OFF SOUTH							
VTN/DD B1	-.413	-.413	.159	.159	.159	.159	.159
VTN/DD B2	-.112	-.112	-.119	-.119	-.119	-.119	-.119
A PARAM C1	.958	1.068	-.709	-.594	-.511	-.446	-.394
A PARAM C2	.040	.047	.071	.067	.065	.066	.067

MILWAUKEE, WISCONSIN LATITUDE = 42.6

	TR40	TR45	TR50	TR55	TR60	TR65	TR70
DUE SOUTH	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)	(M=12)
VT1/DD	32.05	24.47	19.89	16.44	14.10	12.33	10.95
VT2/DD	27.42	20.94	16.84	14.07	12.06	10.55	9.37
VT3/DD	23.82	18.19	14.63	12.22	10.48	9.16	8.14
ANNUAL DD	1891	2693	3623	4673	5865	7212	8708
PARAMETER A	.597	.654	.708	.753	.793	.833	.866
OFF SOUTH							
VTN/DD B1	.312	.312	.312	.312	.312	.312	.312
VTN/DD B2	-.110	-.110	-.110	-.110	-.110	-.110	-.110
A PARAM C1	.091	.044	.008	-.018	-.038	-.056	-.072
A PARAM C2	.042	.045	.048	.050	.053	.055	.059

CASPER, WYOMING — LATITUDE = 42.6

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	66.92	52.86	42.11	34.52	29.22	25.30	22.31
VT2/DD	59.13	45.35	36.16	29.64	25.09	21.73	19.16
VT3/DD	51.41	39.43	31.44	25.77	21.82	18.89	16.66
ANNUAL DD	2112	3003	4046	5212	6496	7892	9404
PARAMETER A	.559	.540	.536	.549	.555	.560	.560
OFF SOUTH							
VTN/DD B1	-.159	-.159	.518	.518	.518	.518	.518
VTN/DD B2	-.123	-.123	-.127	-.127	-.127	-.127	-.127
A PARAM C1	.620	.640	-1.812	-1.760	-1.727	-1.698	-1.678
A PARAM C2	.089	.102	.129	.138	.149	.161	.174

CHEYENNE, WYOMING — LATITUDE = 41.1

DUE SOUTH	TR40 (M= 2)	TR45 (M= 2)	TR50 (M= 2)	TR55 (M= 2)	TR60 (M= 2)	TR65 (M= 2)	TR70 (M= 2)
VT1/DD	78.65	59.68	47.62	39.43	33.62	29.31	25.97
VT2/DD	66.83	50.71	40.47	33.51	28.57	24.91	22.07
VT3/DD	57.96	43.98	35.09	29.06	24.78	21.60	19.14
ANNUAL DD	1859	2684	3678	4821	6120	7573	9141
PARAMETER A	.535	.525	.510	.496	.483	.472	.451
OFF SOUTH							
VTN/DD B1	-.098	-.098	-.098	-.098	-.098	-.098	-.098
VTN/DD B2	-.088	-.088	-.088	-.088	-.088	-.088	-.088
A PARAM C1	-.332	-.237	-.118	.019	.166	.317	.487
A PARAM C2	-.028	-.013	.002	.019	.037	.057	.082

ROCK SPRINGS, WYOMING — LATITUDE = 41.4

DUE SOUTH	TR40 (M=12)	TR45 (M=12)	TR50 (M=12)	TR55 (M=12)	TR60 (M=12)	TR65 (M=12)	TR70 (M=12)
VT1/DD	64.32	50.35	41.31	35.02	30.39	26.85	24.04
VT2/DD	55.26	43.26	35.49	30.09	26.11	23.07	20.65
VT3/DD	45.05	37.61	30.86	26.16	22.71	20.06	17.96
ANNUAL DD	2546	3528	4645	5882	7245	8729	10317
PARAMETER A	.445	.463	.472	.472	.470	.464	.450
OFF SOUTH							
VTN/DD B1	.111	.111	.111	.111	.111	.111	.111
VTN/DD B2	-.129	-.129	-.129	-.129	-.129	-.129	-.129
A PARAM C1	.611	.589	.587	.599	.615	.640	.680
A PARAM C2	.124	.137	.153	.173	.194	.217	.247

SHERIDAN, WYOMING — LATITUDE = 44.5

DUE SOUTH	TR40 (M= 1)	TR45 (M= 1)	TR50 (M= 1)	TR55 (M= 1)	TR60 (M= 1)	TR65 (M= 1)	TR70 (M= 1)
VT1/DD	37.65	30.41	25.37	21.74	19.02	16.90	15.21
VT2/DD	32.27	26.07	21.75	18.64	16.30	14.49	13.04
VT3/DD	28.05	22.66	18.90	16.20	14.17	12.59	11.33
ANNUAL DD	2051	2883	3858	4990	6277	7709	9256
PARAMETER A	.809	.786	.768	.761	.758	.756	.748
OFF SOUTH							
VTN/DD B1	-.001	-.001	-.001	-.001	-.001	-.001	-.001
VTN/DD B2	-.118	-.118	-.118	-.118	-.118	-.118	-.118
A PARAM C1	.106	.131	.155	.171	.179	.184	.192
A PARAM C2	.026	.034	.043	.052	.061	.070	.081

Appendix H: Air Force Installation Cost Index

Installation	Closest City	Cost Adjustment factor (weighted average)
Altus	Lawton OK	0.918
Andrews	Washington DC	0.954
Arnold	Chattanooga TN	0.880
Barkdsdale	Sherveport LA	0.896
Beale	Sacramento CA	1.150
Bergstrom	Austin TX	0.930
Blytheville	Memphis TN	0.925
Bolling	Washington DC	0.954
Brooks	San Antonio TX	0.903
Cannon	Albuquerque NM	0.939
Carswell	Dallas TX	0.961
Castle	Fresno CA	1.117
Chanute	Decatur IL	0.982
Charleston	Charleston SC	0.839
Columbus	Tuscaloosa AL	0.864
Davis-Monthan	Tucson AZ	0.973
Dover	Wilmington DE	0.994
Dyess	Abilene TX	0.887
Edwards	Bakersfield CA	1.070
Eglin	Mobile AL	0.904
Ellsworth	Rapid City SD	0.889
England	Baton Rouge LA	0.934
Fairchild	Spokane WA	1.051
Francis E Warren	Cheyenne WY	0.994
George	Los Angles CA	1.113
Goodfellow	Abilene TX	0.887
Grand Forks	Fargo ND	0.925
Griffiss	Utica NY	0.941
Grissom	Fort Wayne IN	0.948
Gunter	Montgomery AL	0.857
Hanscom	Boston MA	1.046
Hill	Salt Lake City UT	0.969
Holloman	Albuquerque NM	0.939
Homestead	Miami FL	0.919
Hurlburt	Mobile AL	0.904
Indian Springs	Las Vegas NV	1.079
Keelser	Biloxi MS	0.886
Kelly	San Antonio TX	0.903
Kirtland	Albuquerque NM	0.939
K. I. Sawyer	No Adjustment	1.000
Lackland	San Antonio TX	0.903
Langley	Norfolk VA	0.858
Laughlin	San Antonio TX	0.903

Appendix H (cont.): Air Force Installation Cost Index

Installation	Closest City	Cost Adjustment Factor (Weighted Average)
Little Rock	Little Rock AR	0.887
Loring	No Adjustment	1.000
Los Angles	Los Angles CA	1.113
Lowry	Denver CO	1.016
Luke	Phoenix AZ	0.978
MacDill	Tampa FL	0.930
Malstrom	Great Falls MT	0.948
March	Los Angles CA	1.113
Mather	Sacramento CA	1.150
Maxwell	Montgomery AL	0.857
McChord	Seattle WA	1.065
McClellan	Sacramento CA	1.150
McConnell	Wichita KS	0.908
McGuire	Trenton NJ	1.001
Minot	No Adjustment	1.000
Moody	Albany GA	0.861
Mountain	Boise ID	0.958
Myrtle Beach	Chareston SC	0.839
Nellis	Las Vegas NV	1.079
Norton	Los Angles CA	1.113
Offut	Omaha NE	0.960
Patrick	Orlando FL	0.853
Pease	Maneschester NH	0.918
Petersen	Colorado Springs CO	0.960
Plattsbugh	Burlington VT	0.892
Pope	Raleigh NC	0.828
Randolph	San Antonio TX	0.903
Reese	Lubbock TX	0.894
Robins	Macon GA	0.860
Scott	St Louis MO	0.978
Seymour-Johnson	Raleigh NC	0.828
Shaw	Columbia SC	0.835
Sheppard	Wichita Falls TX	0.898
Tinker	Oklahoma City OK	0.936
Travis	San Francisco CA	1.224
Tyndall	Tallahassee FL	0.839
USAF Academy	Colorado Srings CO	0.960
Vance	Oklahoma City OK	0.936
Vandenberg	Bakersfield CA	1.070
Whiteman	Kansas City MO	0.988
Williams	Phoenix AZ	0.978
Wright-Patterson	Dayton OH	0.992
Wurtsmith	Flint MI	0.988

Appendix I: System Costs
(units = $/square foot of Ac)

Table I.1

Direct Gain (Csol)

System Number	TWF				
	0.00	0.25	0.50	0.75	1.00
3401	22.67	23.59	24.52	25.44	26.36
3402	26.49	27.41	28.34	29.26	30.18
3441	27.72	28.64	29.57	30.49	31.41
3442	31.54	32.46	33.39	34.31	35.23
3491	28.48	29.40	30.33	31.25	32.17
3492	32.30	33.22	34.15	35.07	35.99
3601	24.53	25.37	26.21	27.05	27.89
3602	28.35	29.19	30.03	30.87	31.71
3641	29.58	30.42	31.26	32.10	32.94
3642	33.40	34.24	35.08	35.92	36.76
3691	30.34	31.18	32.02	32.81	33.70
3692	34.16	35.00	35.84	36.68	37.52
6401	30.71	32.56	33.40	36.25	38.09
6402	34.53	36.38	38.22	40.07	41.91
6441	35.76	37.61	39.45	41.30	43.14
6442	39.58	41.43	43.27	45.12	46.96
6491	36.52	38.37	40.21	42.06	42.90
6492	40.34	42.19	44.03	45.88	47.72
6601	34.43	36.11	37.79	39.47	41.15
6602	38.25	39.93	41.61	43.29	44.97
6641	39.48	41.16	42.84	44.52	46.20
6642	43.30	44.98	46.66	48.34	50.02
6691	40.24	41.92	43.60	45.28	46.70
6692	44.06	45.74	47.42	49.10	50.78
9401	38.75	41.52	44.29	47.05	49.82
9402	42.57	45.34	48.11	50.87	53.64
9441	43.80	46.57	49.34	52.10	54.87
9442	47.62	50.39	53.16	55.92	58.69
9491	44.46	47.33	50.10	52.86	55.63
9492	48.38	51.15	53.92	56.68	59.45
9601	44.33	46.85	49.37	51.89	54.41
9602	48.15	50.67	53.19	55.71	58.23
9641	49.38	51.90	54.42	56.94	59.46
9642	53.20	55.72	58.24	60.76	63.28
9691	50.14	52.66	55.18	57.70	60.22
9692	53.96	56.48	59.00	61.52	64.04

Appendix I (cont.): Systems cost

Table I.2

Direct Gain (Cnorm)

System Type/ number	SWF	TWF 0.00	0.25	0.50	0.75	1.00
Brick/3XXX	0.05	20.45	20.08	19.70	19.83	18.95
	0.10	21.37	20.99	20.62	20.24	19.87
	0.15	22.28	21.90	21.53	21.15	20.78
Block/3XXX	0.05	18.03	17.68	17.28	16.91	16.53
	0.10	18.95	18.57	1820	17.82	17.45
	0.15	19.86	19.48	19.11	18.73	18.36
Metal/3XXX	0.05	16.81	16.44	16.06	15.69	15.31
	0.10	17.73	17.35	16.98	16.60	16.23
	0.15	18.64	18.26	17.89	17.51	17.14
Brick/6XXX	0.05	28.49	27.94	26.99	26.24	25.49
	0.10	29.41	28.66	27.91	27.16	26.41
	0.15	30.32	29.57	28.82	28.07	27.32
Block/6XXX	0.05	26.07	25.32	24.57	23.82	23.07
	0.10	26.99	26.24	25.49	24.74	23.99
	0.15	27.90	27.15	26.49	26.65	24.90
Metal/6XXX	0.05	24.85	24.10	23.35	22.60	21.85
	0.10	25.77	25.02	24.27	23.52	22.77
	0.15	26.68	25.93	25.18	24.43	23.68
Brick/9XXX	0.05	36.53	35.41	34.28	33.16	32.03
	0.10	37.45	36.32	35.20	34.07	32.95
	0.15	38.36	37.23	36.11	34.99	33.86
Block/9XXX	0.05	34.11	32.99	31.86	30.74	29.61
	0.10	35.03	33.90	32.78	31.65	30.53
	0.15	35.94	34.81	33.69	32.56	31.44
Metal/9XXX	0.05	32.89	31.77	30.64	29.52	28.39
	0.10	33.81	32.68	31.56	30.43	29.31
	0.15	34.72	33.59	32.47	31.34	30.22

Table I.3

Indirect Gain (Cnorm)

Ext Wall Construction	SWF 0.05	0.10	0.15
Brick	12.41	13.32	14.24
Block	10.00	10.91	11.82
Metal	8.78	9.69	10.60

Appendix I (cont.): Systems cost

Table I.3

Indirect Gain (Csol)

System type	System number	Csol
Vented Trombe Wall	1202	29.48
	2201	25.48
	2202	31.57
	2291	31.08
	2292	37.08
	3202	33.07
Unvented Trombe Wall	1202	27.85
	2201	23.64
	2202	29.64
	2291	35.45
	3202	31.44
Concrete Block Wall	11	17.80
	12	23.80
	21	20.48
	22	26.48

Appendix J: Worksheets (Wray, 1983:26)

Worksheet No. 1
SCHEMATIC DESIGN PARAMETERS

Building Size

Heated floor space: Af = ________ sf

Ceiling height: h = ________ ft

Total external perimeter: Pt = ________ ft
(Include external perimeter of each floor)

External surface area: Ae = ________ sf
(Ae = 2 * Af + h * Pt)

External surface-area-to-floor-area ratio: Ae/Af = ________

Insulation Levels (units = sf $^{\circ}$ F h/BTU)

Rwall = ________
(Rwall is obtained from the contour map in Figure 3.4.)

Rwall = 1/3 * (Ae/Af) * Rwall = ________

Rroof = 1.5 * Rwall = ________

Rperim
or = .75 * Rwall = ________
Rbase

Solar Aperature Size

(Ac/Af)o = ________
(The above ratio is obtained from the contour map in Figure 3.4)

Ac = 1/3 * Af * (Ac/Af)o * (Ae/Af) = ________ sf

Worksheet No. 2
ESTIMATION OF BUILDING LOAD COEFFICIENT

Specified Design Parameters

Ground floor perimeter:	Pg =	________	ft
Ground floor area:	Ag =	________	sf
Roof area: (horizontal projection)	Ar =	________	sf
South wall area: (includes windows and solar aperature)	As =	________	sf
Nonsouth window fraction:	NSF =	________	
Number of glazings in nonsouth windows:	NGL =	________	
Air changes per hour:	ACH =	________	
Air density ratio:	ADR =	________	

Calculated Design Parameters

Nonsouth window area: (An = [Pt * h - As] * NSF)	An =	________	sf
Wall area: (Aw = Pt * h - Ac - An and is the total area of all external walls excluding windows and solar aperatures.)	Aw =	________	sf

Building Load Coefficient (units = BTU/DD)

Walls: (Lw = 24 * Aw/Rwall)	Lw =	________
Nonsouth windows: (Ln = 26 * An/NGL)	Ln =	________
Perimeter (slab on grade): (Lp = 100 * Pg/[Rperim + 5])	Lp =	________
or		
Basement (heated): (Lb = 256 * Pg/[Rbase + 8])	Lb =	________
or		
Floor (over vented crawl space: (Lf = 24 * Ag/Rfloor)	Lf =	________

Worksheet No. 2 (cont.)
ESTIMATION OF BUILDING LOAD COEFFICIENT

Roof: (Lr = 24 * Ar/Rroof)	Lr = ________
Infiltration:	Li = ________
Total:	BLC = ________

Worksheet No. 3
SYSTEM PARAMETERS

First System

System type: ____________

System number : ________

Scale factor: F1 = ________

Effective aperature conductance: G1 = ________
(BTU/^{o} F day sf)

System-state aperature conductance: Uc1 = ________
(BTU/^{o} F h sf)

System solar absorptance: α = ________

Collection aperature area: Ac1 = ________ sf

Second System

System type: ____________

System number: ________

Scale factor: F2 = ________

Effective aperature conductance: G2 = ________
(BTU/^{o} F day sf)

System-state aperature conductance: Uc2 = ________
(BTU/^{o} F h sf)

System solar absorptance: α = ________

Collection aperature area: Ac2 = ________ sf

First System Fraction

f1 = Ac1/(Ac1 + Ac2)

Second System Area Fraction

f2 = Ac2/(Ac1 + Ac2)

Worksheet No. 3 (cont.)
SYSTEM PARAMETERS

Mixed System Parameters

Scale factor: $F = f1 * F1 + f2 * F2 =$ ________

Effective aperature conductance (daily): $G = f1 * G1 + f2 * G2 =$ ________

Steady State aperature conductance (hourly): $Uc = f1 * Uc1 + f2 * Uc2 =$ ________

System solar Absorptance: $\bar{\alpha} = f1 * \alpha 1 + f2 * \alpha 2 =$ ________

Collection aperature area: $Ac = Ac1 + Ac2 =$ ________

Worksheet No. 4
WEATHER PARAMETERS

Location and System Data

State: ______________

City: ______________

Thermostat setpoint: Tset = ______________
(^{o} F)

Internal heat generation rate: Qint = ______________
(BTU/day)

Base temperature: Tb = ______________
(^{o} F)
(Tb = Tset - Qint/(BLC + 24 * Uc * Ac))

Number of glazings on first solar aperature: NGL1 = ______________

Number of glazings on second solar aperature: NGL2 = ______________

Area-weighted system glazing number: NGL = ______________
(NGL = F1 * NGL1 + F2 * NGL2)

Weather Parameters for Due South Orientation

Transmitted-radiation-to-degree-day ratio : (VT/DD)o = ______________
(Btu/sf DD)

City parameter: a_o = ______________

Annual Heating Degree Days: DDy = ______________

Workseet No. 5
ESTIMATION OF CONVENTIONAL BUILDING LOAD COEFFICIENT

Maximum Transmission Levels (BTU/sf $^{\circ}$ F h)

Walls: Uo = ________

Roof: Ur = ________

Floor: (over vented crawl space) Uf = ________

Perimeter: (slab on grade) Up = ________

Note: Uo, Ur, Uf, and Up are obtained from ETL 83-9.

Perimeter R-value (sf $^{\circ}$ F h/BTU)

Rperim = 1/Up = ________

Conventional Building Load Coefficient (BTU/DD)

Gross walls: Lw = ________
(Lw = 24 * Pt * h * Uo)

Roof: Lr = ________
(Lr = 24 * Ar * Ur)

Floor: Lf = ________
(Lf = 24 * Ag * Uf)
or
Perimeter: Lp = ________
(Lp = 100 * Pg/(Rperim + 5)

Infiltration: Li = ________

Total: BLCnorm = ________

Worksheet No. 6
ESTIMATION OF YEARLY ENERGY SAVINGS

The Scaled Solar Load Ratio

$$SLR^* = \frac{F * (VT/DD) * \alpha}{BLC/Ac + G} = \_\_\_\_\_\_$$

The Yearly Heat-to-Load Ratio

(Qaux/Qload) = ______

Yearly Auxiliary Heat Requirement (MBTU)

Qaux = ______
(Qaux = (Qaux/Qload) * (BLC + G * Ac) * DDy)

Yearly Normal Heat Requirement (MBTU)

Qnorm = BLCnorm * DDy = ______

Yearly Solar Energy Savings (MBTU)

SS = Qnorm - Qaux = ______

Worksheet No. 7
ESTIMATION OF SOLAR ADD-ON COST

Building and Location Data

Exterior wall construction: ________

City Cost Index: CCI = ________

First System (cost = $/sf)

System Type: ____________

System Number: ________

Thermal wall fraction: TWF = ________

Solar system unit cost: Csol = ________ $/sf

Normal construction unit cost: Cnorm = ________ $/sf

System Differential Cost: SDC1 = ________

Second System (cost = $/sf)

System Type: ________

System Number: ________

Thermal wall fraction: TWF = ________

Solar system unit cost: Csol = ________

Normal construction unit cost: Cnorm = ________

System Differential Cost: SDC2 = ________

Mixed System Differential Cost

SDC = SDC1 + SDC2 = ________

Solar Add-on Cost (units = $)

SAC = SDC * CCI = ________

Worksheet No. 8
ESTIMATION OF SAVINGS TO INVESTMENT RATIO

Energy Data

Fuel type: ____________

Fuel cost: Fc = ________
(\$/MBTU)

Fuel efficiency eff = ________

Uniform Present Worth Factor UPWF = ________

Savings to Investment Ratio

$$SIR = \frac{SS * Fc * UPWF}{0.9 * SAC * eff}$$

Electricity = ________

Natural Gas = ________

Distillate Oil = ________

Appendix K: <u>Project Booklet Worksheet</u> (Willet, 1984)

PROJECT BOOK CHECKLIST

TAB

M - ENERGY CONSIDERATIONS

1. General
   - a. DOE Region
   - b. Energy Budget Figure (EBF)
   - c. Energy efficient equipment criteria
   - d. Computer bldg. analysis req. (for new construction)
   - e. Least life cycle cost analysis (for retrofit construction)
   - f. Energy Management and Control System
     1. Existing system (type, size, location, etc.)
     2. Plans for future EMCS
     3. Single bldg controller
   - g. Types of energy required
     1. Cost/MBTU
     2. Availability

2. Solar Energy
   - a. Passive solar considerations
     1. Bldg orientation, siting configuration
     2. Vestubile req.
     3. Window req.
     4. Insulation optimization
     5. Passive solar economic summary
   - b. Unique passive solar considerations
     1. Attached greenhouses
     2. Atriums
     3. Trombe walls
     4. Daylighting/skylighting
     5. other applications
     6. Unique passive solar economic summary
   - c. Active solar considerations
     1. Bldg heating, air conditioning, domestic hot water
     2. Heating process water
     3. Roof or ground mounted collector
     4. Liquid, chemical, or rock storage
     5. Freeze protection
     6. Active solar preliminary assessment

TAB

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VITA

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Vita

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